JOHN Felesky

DRAINAGE INSPECTION

PENNSYLVANIA

DEPARTMENT OF HIGHWAYS

INSPECTOR CERTIFICATION SERIES

DRAINAGE INSPECTION

Inspector Certification Series

by

Charles G. Algier

Assistance in the preparation of this manual was provided by:

Raymond Feeman	Construction Engineer II, District 8-0
John Weise	Construction Engineer I, District 8-0
Richard J. Bell, Jr.	Construction Engineer I, District 8-0
John Stitley	Construction Inspector, District 8-0

Acknowledgement is also made to the Armco Drainage and Metal Products, Inc. for permission to reproduce excerpts from one of its publications, "Handbook of Drainage and Construction Products".

DRAINAGE INSPECTION

INTRODUCTION

You have been selected to pursue this course of instruction in Drainage Inspection because your work record indicates that you are capable of and have the desire to perform creditably in this skills area.

If you are a District employee, your District Construction Engineer has decided that you can and will be able to do a good job in Drainage Inspection. He has also determined that qualification in this field can open the door for you into other areas of Construction Inspection.

Successful completion of this course will result in your certification as a qualified inspector of Drainage Operations for the Pennsylvania Department of Highways.

Every Drainage Inspector must become qualified. Although experienced men will complete the course rapidly and easily, all must qualify.

As time permits, all Construction Inspectors should qualify. Since no highway can be better than the foundation it is built on, it is important that all inspectors be knowledgeable in this field. Certification can become your passport to success.

This course consists of the following:

SECTION I DRAINAGE OPERATIONS

This section includes a breakdown of the various operations involving Drainage, in sub-sections. Each sub-section contains questions

to which you must write answers, as they occur. When you finish this section, you should then get from your supervisor and complete the comprehensive written examination which accompanies this section.

SECTION II DRAINAGE INSPECTION

This section contains a series of sub-sections on your various duties as a Drainage Inspector. It includes problems in computations, making of gradations, the physical inspections you must make, and sampling of materials. You should begin this section as soon as you have completed Section I. Again, when Section II is completed, you should get from your supervisor and complete the comprehensive written examination which accompanies this section.

SECTION III REPORTS AND RECORDS

In this section there appear forms and records which make up the permanent record of Drainage Operations. You will also find situations and are required to complete the various items of information which appear on the various forms, on your own. Again, there is a comprehensive written quiz you should request and take.

Upon completion of the above three sections, and after attaining a passing grade in the three written examinations, you should take the performance test. In this, you will be observed as you perform Drainage inspection duties. This test will be given by your supervisor or a certified Drainage Inspector. Depending on his (and your) normal duties, and project operations, it may take more than one day. You may have to perform parts of it more than once to prove your ability. (This could hold true in the written examinations, also.)

After you have passed all of the above, your District Construction Engineer will certify you as a qualified Drainage Inspector, based upon knowledge you have gained and your overall job performance record.

This certification consists of a printed form which will be kept in your personal folder in the District Office. In addition, you will receive a wallet card identifying you as a qualified Drainage Inspector.

SECTION I

BASIC PRINCIPLES AND PRACTICES IN DRAINAGE CONSTRUCTION

General Considerations:

In the construction of a highway, drainage is one of the most essential elements to be considered. There are three problems involved:

(a) Disposal of surface water from the roadway section.

(b) Spanning of streams or man-made drainage channels.

(c) Elimination or control of subsurface water.

Surface water on a highway creates a hazard to driving, which is made worse by the water freezing. It also causes erosion and expensive maintenance. It may seep into the subgrade, thereby removing support from the roadway surface and shoulders.

Location Considerations:

Early roads generally followed the ridges, the contours, or the valleys, with stream crossings or mountain passes being the control points. With heavier traffic, came the need for straighter alignment, smoother grades and wider roadbeds. This requires deeper cuts and higher fills. This also exposes greater areas where direct precipitation (rain) must be handled.

The Location engineer and the designer should know what effect their work has on the adjoining land. Present stream channels cannot be blocked to flood upstream property, nor should run-off erode bordering land. Natural stream courses should be altered as little as possible unless to improve conditions.

Cross Section of Roadway:

A standard roadway cross-section reveals several phases of controlling surface water. In a cut section the road surface is first "insulated" from water that falls on adjacent areas by means of a ditch section. This may be supplemented by an intercepting ditch or subdrain

at some point on or behind the backslope, but only if surface run-off is excessive.

For excessive flow against a fill section, an intercepting ditch, sod, revetment, sheeting or a retaining wall will resist direct erosion.

Crown:

Sloping the roadway to the side will shed the water from the path of traffic. For earth and low-type surfaces, the crown recommended is about $\frac{1}{2}$ inch per foot of width of roadway; on high-type pavements, as little as 1/8 inch per foot. Shoulders should generally slope not more than one inch per foot. A common mistake is to have the outer edge of the shoulder higher than the pavement.

A minimum longitudinal grade line of 0.5 percent is desirable to provide adequate drainage lengthwise of the roadway. Steeper grades may be required in the ditch.

Side Slopes:

Rain or melting snow drained to the edge of the road surface will ordinarily flow over the shoulder in a broad sheet or series of rivulets and down the side slope to a side ditch or the natural ground. Side slopes vary from 4 to 1 on shallow fills to as steep as $1\frac{1}{2}$ to 1 on high fills. Vegetation, or some type of erosion resisting material is desirable on side slopes.

Shallow Gutters:

Where shoulders or side slopes are easily eroded, an intercepting curb and gutter may be built beyond the edge of the pavement, preferably near the outer edge of the shoulder so as not to restrict traffic.

Curbs and gutters are also used where side ditches are considered hazardous or undesirable as in built-up areas, along parkways and on express highways. They should be far enough from the traffic

lane so vehicles need not travel in a trough of water. Tip curbs built up to a height of 2 or 3 inches along the pavement edge to prevent shoulder erosion were once popular, but because of the hazard are no longer recommended.

The design of gutters for capacity is the same as for triangular ditches. Usually the water should be out-letted down the embankment or into storm sewers at frequent intervals. Gutters and curbs may both be built of bituminous paving material, concrete, stones set in grout, or other erosion-resistant materials.

Median Strips:

On dual lane or divided highways, the median strip, grassed wall or island, may vary in width from a few feet to several hundred feet. The latest practice in most states is to depress the median strip if it exceeds about 20 feet in width.

Depressing the median strip aids surface drainage, serves as a storage space for plowed snow, and tends to keep melting snow and ice off the pavement.

Large Paved Areas:

At wide intersections, interchanges and their approaches, surface water is removed by crowning or warping the surface to conduct the water to low areas or to the edges where various types of inlets or gratings will transfer the water to a storm sewer system. Gratings must be large enough to handle all of the water promptly and to allow the sewer to utilize its full capacity.

Bridge Surfaces:

On bridges or overpasses more than 100 feet in length, the surface

water conducted to the edges of the roadway should pass through grates in the gutter at intervals of 50 feet or at each bent or pier, discharging either into the air or into downspouts.

Side Ditches:

Side ditches along a roadway serve to intercept surface water from the roadway (pavement, shoulder, side slope). In a cut section they also intercept flow from the backslope. In snow country, the side ditch provides storage space for snow. Side ditches are of limited value in lowering the water table under a roadway.

Where side ditches are objectionable or unsafe, it may be desirable to use a gutter, a steam enclosure, or a storm drain.

NOW ANSWER THESE QUESTIONS

1. What are the three general problems involved in highway drainage?

DISPOSAL of SURFACE WATER [illegible]

[illegible] of STREAMS [illegible]

[illegible] of CONTROL of SUBSURFACE WATER

2. How is surface water controlled in a standard roadway cross-section?

CUT AREA BY [illegible] SECTION, ALSO INTERCEPTING DITCH [illegible]

FILL AREA — INTERCEPTING DITCH, SOD, [illegible]

3. What does the "crown" of a roadway have to do with drainage?

WILL SHED THE WATER [illegible]

EARTH ROAD 1/2" PER FT

PAVED 1/4" TO 1/2" PER FT

SHOULDERS — [illegible] 1" PER FT

[illegible] LONGITUDINAL SLOPE

4. When are curbs and gutters recommended for drainage?

5. What are three benefits of a Median Strip?

6. How is drainage accomplished:

   a) At an interchange?

   b) On bridges or long overpasses?

7. What are some benefits of side-ditches?

SUBSURFACE DRAINAGE

Soils, even though the most abundant of all materials to be used in engineering works, have until recently received little consideration in comparison to their importance. Since they are made up of natural materials varying both in physical and chemical characteristics, and with no control possible in their creation, their proper use was very limited until the modern concept of soil mechanics was introduced in the United States some thirty years ago. Since that time, great strides have been made in the use of soils for actual structures such as dams and levels. Methods have been developed for improving soils by various treatments so that they will sustain greater loads and better resist the ravages of time.

As roadbeds and foundations for modern transportation facilities and structures, soils must be strong. Strength can be increased and controlled by (1) regulation of water content, (2) chemical additives, (3) proper gradation of natural soils and (4) compaction. Regardless, of the treatment chosen, the intrusion of excessive water after construction will weaken or even destroy the desired foundation. Therefore, it is particularly important that there should be a clear understanding as to the effect of water in its relation to soils.

Soils are primarily of mineral origin, being formed by the disintegration of rocks through the agency of wind, water, ice, frost, temperature changes, chemical action, plant growth and animal life. In addition, to the rock or mineral constituent, soils contain organic matter extracted from the air and from the vegetation which has grown in the soil. Also there are many forms of minute animal life in the soil which influence drainage and plant growth. Whether the soil be sedentary or transported, its principal constituents are silicates.

SUB-DRAINAGE

Spring is known to be the bad time of the year for roads - the time when breakups occur. That is when the frost goes out. At other seasons, especially after rains, water flows freely from joints and cracks in the road surface. Mud pumping occurs.

Results are rough, broken, dangerous pavements. Maintenance and repair costs are high. Next year the trouble is repeated. A rapid increase in the amount of traffic, traveling at higher speeds, and a greater proportion of heavy truck and bus traffic has made the situation worse.

The cause of the trouble is almost always the same - "too much water and not enough drainage".

IMPORTANCE OF A DRY FOUNDATION

Although water is easily recognized as the cause of the trouble, the method of overcoming it is not universally understood. Instead of removing the cause, the tendency too often is to treat the symptoms - namely, by adding gravel, patching the surface, or resurfacing the whole pavement.

If a sufficiently firm roadbed could be obtained, any thin surface which would not shatter under traffic and which would withstand abrasive wear, would be sufficient.

All highway surfaces depend upon the underlying earth for their support. If that support is weak, or lacks uniformity, it may fail to fulfill its function. Further, if improved surfaces are built upon soils which at certain seasons are subject to extreme changes in volume, not only is support lacking, but destructive counter stresses may be developed which will result in serious heaves, frost boils, excessive pavement cracking and similar troubles. No type or design of surface is capable of resisting these forces. It becomes evident, therefore, that the design of the road should

begin with the subgrade, and that effective preventive measures taken in the initial stages of construction will be reflected by ultimate economy in maintenance.

SURFACE VERSUS BASE

There are several ways of providing a road surface strong enough to carry traffic. If the native soil has good natural drainage, all that may be required is a waterproofing of the surface and stabilizing or strengthening of the top few inches of soil.

Heavier traffic requires a stronger surface or pavement. Under this may be a compacted impervious base or a pervious one. This in turn is supported by the native subgrade (in a cut) or by a fill built upon the native soil or foundation.

The drier each one of these strata is within limits, the less thickness is required. There is a direct relationship between drainage and economy of construction.

Soil surveys to locate free ground water will usually indicate one of the following conditions:

a) Sidehill seepage.

b) Level water table.

c) Surface leakage.

Depending upon the kind of soil, capillary water may rise from the first two conditions.

Sidehill seepage should be intercepted, preferably before the water enters the roadway area. For level water table conditions, it may be possible to lower the water table below the effective capillary limit by means of subdrainage pipe.

NOW ANSWER THESE QUESTIONS

1. What are four methods which have been developed to aid subsurface drainage through the soil under a roadway?

   Regulation of water content
   Chemical Additives
   Proper gradation of natural soil
   Compaction

2. What are some of the materials which constitute "soil"?

   Disintegration of Rocks by frost, wind, ice
   Temperture change
   Organic matter extracted from the air

3. What are some conditions which appear in a roadway during the springtime?

   Breakups occur
   Mud pumping occurs
   Rough + Broken pavement

4. What are some of the things which occur when a good surface is placed over an unsatisfactory soil condition?

   serious Road Heaves, frost boils
   Excessive Road cracking

5. What do soil surveys to locate free ground water usually indicate?

   Sidehill seepage
   Level water table
   Surface leakage

FOUNDATION FOR STRUCTURES

It is essential that the foundation under a structure provide support as firm and as nearly uniform as possible under the entire bearing surface. Whenever conditions permit, the bottom of the excavation should be on solid ground for its full length and width. If it can be avoided, culverts should not be placed partly on filled ground and partly on undisturbed ground, because of the probability of unequal settlement which might distort or break the structure. This applies transversely as well as longitudinally and when a sidehill location is used the culvert should be benched into the hillside far enough to be entirely on solid ground. If part of the culvert must be on filled ground, the filled material should be placed on thin layers and thoroughly compacted so that it will provide a foundation as nearly comparable to that afforded by the natural ground as possible.

The installation of drainage structures or systems in embankments should be avoided whenever practicable to do so because of the possibility of not providing a firm foundation and of settlement which would cause breakage of the structure or low spots which would not drain. When such an installation must be made, the embankment should be constructed and thoroughly compacted to a minimum height of 4 feet, where practicable, above the top of the pipe. Shallow installations, with less than 4 feet of cover over the pipe, should be constructed after all heavy hauling is done.

NOW ANSWER THESE QUESTIONS

1. What is the purpose of a roadway foundation?

Provide support to pavement

2. What is the ideal condition for the bottom of a roadway excavation?

TO BE UNIFORM UNDER THE ENTIRE BEARING SURFACE

3. What must be done when part of a culvert is on filled ground?

THE CULVERT SHOULD BE BENCHED FAR ENOUGH [illegible] SOLID GROUND, IF HALF SOLID & HALF FILL THE FILL AREA SHOULD BE PUT IN THIN LAYERS & COMPACTED

4. Why should drainage structures be avoided in embankments, whenever practicable?

YOU WOULDNT HAVE A FIRM FOUNDATION & SETTLEMENT WOULD CAUSE BREAKAGE OF STRUCTURE

5. What must be done when such an installation must be made?

THE EMBANKMENT SHOULD CONSTRUCTED & THOROUGHLY COMPACTED TO A MINIMUM OF 4', WITH LESS THAN 4' TO BE CONSTRUCTED AFTER ALL HEAVY HAULING IS DONE

PRINCIPLES OF CULVERT LOCATION

Culvert location means alignment and grade with respect to both roadway and streams. Proper location is important because it affects the adequacy of the opening, maintenance of the culvert and possible washout of the roadway. Although every culvert installation is a separate problem, a few principles are explained here to apply in a majority of cases.

A culvert is an enclosed channel serving as a continuation of and a substitute for an open stream wherever that stream meets an artificial barrier such as a roadway embankment or a levee. It is necessary to give consideration to abutting property both as to ponding upstream and to safe velocities to avoid undue scour or silting downstream.

An open stream is not always stable. It may be changing its channel, straightening itself in some places and becoming more crooked in others. It may be scouring itself deeper in some places, silting in others. Change of land use upstream by clearing, deforestation or real estate development may change both the stability and the flood flow of a stream.

Because a culvert is a fixed line in a stream, judgment is necessary in properly locating the structure.

ALIGNMENT OF A CULVERT

The first principle of culvert location is to give the stream a direct entrance and a direct exit. Any abrupt change in direction

at either end will retard the flow and make a larger structure necessary.

A direct inlet and outlet, if not already existent, can be obtained in one of three ways, by means of a channel change, a skewed alignment or both. The cost of a channel change may be partly offset by a saving in culvert length or decrease in size. A skewed alignment requires a greater length of culvert but is usually justified by improving the hydraulic condition and the safety of the roadbed.

For correct fabrication of corrugated metal drainage structures with cut ends, it is necessary to specify the direction as well as the angle of the skew, particularly for Paved-Invert type pipe, Multi-Plate arches and pipe arches.

The second principle of culvert location is to use reasonable precautions to prevent the stream from changing its course near the ends of the culvert. Otherwise the culvert may become inadequate, cause excessive ponding and possibly wash out or require expensive maintenance of the roadway. Riprap, sod, paving or metal end sections will help protect the banks from eroding and changing the channel.

NOW ANSWER THESE QUESTIONS

1. What is meant by culvert location?

ALIGNMENT & GRADE WITH RESPECT TO [illegible] ROADWAY & STREAMS

2. Describe a culvert. — ITS A ENCLOSED CHANNEL

3. What is the ideal alignment for a culvert? GIVE STREAM A DIRECT ENTRANCE & DIRECT EXIT

4. How can a direct inlet and outlet for a culvert be obtained, if not already existent? - CHANNEL CHANGE, SKEWED ALIGNMENT

5. What happens when a stream changes its course near the ends of a culvert? CAUSES PONDING, WASH OUT EXPENSIVE MAINTENANCE OF ROADWAY

CULVERTS ON GRADE

The ideal grade line for a culvert is one that produces neither silting nor excessive velocities and scour, one that gives the shortest length and one that makes replacement simplest.

Velocities as great as 10 feet per second cause destructive scour downstream and to the culvert structure itself unless protected. The silt carrying capacity of a stream varies as the square of the velocity.

The capacity of a culvert with a free outlet (not submerged) is not increased by placing it on a slope steeper than the "critical slope" (about 1% for a 96 inch pipe). The capacity is controlled by the amount of water that can get into the inlet. On the other hand, the capacity of a pipe on a very slight gradient and with a submerged outlet is influenced by the head (difference in elevation of water surface at both ends). In this case, the roughness of the culvert interior, in addition to the velocity head and entrance loss is a factor.

A slope of 1 to 2 percent is advisable to give a gradient equal to or greater than the critical slope, provided the velocity is permissible. In general, a minimum slope of 0.5 feet in 100 feet is recommended to avoid sedimentation.

Ordinary practice is to make the grade line coincide with the existing streambed. However, deviation is permissible if for a good purpose, with the approval of the Project Engineer, as follows:

1. In freshly graded areas, on relatively flat gradients, expect semimentation to occur. Set the culvert invert several inches higher than the streambed, but on the same slope.

2. Where headroom is limited, setting a culvert below streambed grade is likely to result in sedimentation and reduced waterway area. Either use a low, wide culvert such as a pipe arch or raise the road grade.

3. Under high fills, anticipate greater settlement of the culvert under the center than under the sides of the fill. Give the culvert camber by laying the upstream half nearly level and putting all the fall in the downstream half.

4. Under high fills, it may not be necessary to place the culvert at streambed level. If some ponding is permissable, the culvert can sometimes be placed in firm ground at a higher level, thus reducing the length and simplifying replacement, should that ever become necessary.

5. In steeply sloping areas, as on hillsides, it is not always necessary to place the culvert on the same steep grade. The culvert can be placed on the "critical" slope and then a spillway or cutoff wall provided at the outlet to prevent undermining. This keeps the culvert shorter and under shallower cover.

6. On steep slopes, it is also possible to use a broken-back grade line under the fill, although this is less desirable. Also a drop inlet or catch basin will help give the culvert a suitable slope.

<u>Remember, the ideal grade line avoids silting, and also avoids high velocities and scour.</u>

<u>NOW ANSWER THESE QUESTIONS</u>

1. What is the ideal grade line for a culvert? ONE THAT PRODUCES NEITHER SILTING NOR EXCESSIVE VELOCITIES & SCOUR

2. Describe "critical slope" of a culvert. - THE MINIMUM SLOPE OF A CULVERT THAT PERMITS THE MAXIUM DISCHARGE OF WATER

3. When may the grade line of a culvert deviate from an existing streambed? IN Freshly graded areas, Flat area

Set culvert several inches higher than streambed

4. What does high velocity of water do to a culvert? - Destructive

Scours

5. How is the capacity of a culvert controlled? Amount of water

that can get into inlet

LENGTH OF CULVERT

The required length of a culvert depends upon the width of the roadway or roadbed, the height of fill, the slope of the embankment, the slope and skew of the culvert, and the type of end finish, such as end section, headwall, beveled end, drop inlet, or spillway.

A culvert should be amply long so the ends are not clogged up by sediment or covered over by a settling spreading embankment. This results in impaired efficiency and increased maintenance. On the other hand, a culvert should not have the ends wastefully exposed.

A cross-sectional sketch of the embankment and a profile of the streambed are perhaps the best means of determining the length of culvert needed. In the absence of such a sketch, the length of a simple culvert under an embankment can be determined as follows:

To the width of the roadway (and shoulders) add twice the slope ratio times the height of fill at the center of the road. The height of fill should be measured to the flow line if headwalls are not to be used and to the top of the culvert if headwalls or end sections are to be installed.

Example:

A roadway is 40 feet wide on top, 2 to 1 side slopes, and at the center of the road the height of fill to flow line is 7 feet (40 + (4 x 7) = 68 feet length at flow line.

If the culvert is on a slope of 5 per cent or more, it may be advisable to compute the sloped length. However, fill slopes usually vary from the established grade stakes so that any refinement in computing culvert length may not be necessary.

NOW ANSWER THESE QUESTIONS

1. What are several conditions which determine the length of a culvert?

2. What happens when a culvert is not long enough?

3. What is the best means of determining the length of a culvert?

4. Describe one formula for computing the length of a culvert.

5. Using the above formula, compute the length of a culvert under a roadway 60 feet in length, slope ratio 1½ to 1, and height of fill to flow line at center of road 6 feet.

60 + (3 x 6) = 60 + 1[illegible]

DEPTH OF COVER OVER CULVERTS

Culverts should be covered with earth, base course and pavement to the depth which will protect them from damage by traffic and fit the alignment, grade and cross-section of the highway. For pipe culverts the minimum depth of cover should be preferably at least 4 feet if heavy equipment is to pass over them during the construction period or afterwards.

NOW ANSWER THESE QUESTIONS

1. In general, how deep should cover over a culvert be?

   TO A DEPTH

2. What is the minimum depth of cover for pipe culverts subjected to heavy loads? 4 FEET

FREE OUTLET CONDITION - CULVERTS

The amount of water a culvert will carry is controlled by several things: the slope of the flow line and streambed above and below, the elevation of the headwater (at inlet), the type of inlet, roughness of culvert interior, and height of the tailwater or backwater.

If a culvert were the same size as the channel above and below, the design problem would be simple. However, a culvert is usually a constriction in the channel, and during flood flow the water will pond upstream from the culvert. If the culvert has a free discharge and sufficient slope, there will be a drop-down of the water surface at the inlet; the velocity increases, but the culvert does not run full. The minimum slope of a culvert that permits the maximum discharge of water is called the "critical slope".

For slopes less than critical, the discharge may be less for a given level of water at the culvert inlet. Slopes steeper than critical will not increase the discharge for any type of culvert, regardless of friction unless it is made to run full by some artificial means. For such cases, the discharge is limited by the amount of water that can enter the pipe.

NOW ANSWER THESE QUESTIONS

1. What controls the amount of water a culvert will carry? – THE SLOPE OF THE FLOW LINE & STREAMBED ABOVE & BELOW THE ELEVATION OF THE HEADWATER (AT INLET)

2. A culvert is usually a constriction (narrowing) of a channel. What can happen in this event? – PONDING OF WATER

3. What happens when the culvert has a free discharge and sufficient slope? - There will be a drop down of the water surface at the inlet, the velocity increases

4. Again, describe "critical slope" in a culvert. The minimum slope of a culvert that permits the maximum discharge of water

5. Will a slope steeper than critical increase the discharge from a culvert? NO

EFFECT OF INLET ON CAPACITY

Experiments show that flared types of inlets are more efficient hydraulically than are straight head walls, square edge entrances and entrances where the culvert projects outward into the inlet pond. In other words, a flared entrance admits more water into a culvert with a free entrance and consequently increases its capacity.

The actual amount of benefit from a flared entrance is variable, depending on its actual slope and conditions prevalent at this point. Various tests have been made for individual conditions, and inlet losses are usually expressed in terms of velocity head. Flared types may be as low as 0.1 of the velocity head loss, whereas projecting sharp entrances may be several times higher.

NOW ANSWER THESE QUESTIONS

1. What are the advantages of flared inlets? - ADmits More WATer iNTO culvert

2. What does the amount of benefit from a flared inlet depend upon?

Depending on its Actual slope

3. How are inlet losses usually expressed? velocity HEAD

STREAM CHANNELS

Importance of Erosion Prevention: Because of the danger of damage to the highway itself and also to adjoining lands, it is essential that provision be made to prevent erosion of adjacent stream channels. This is especially necessary when new channels have been created or when old ones have been changed or disturbed. A channel which has existed for a number of years has usually become so well-established that it is little affected by the erosive forces of the stream. If the alignment, grade or cross-section is changed, however, or if the channel is partly filled so that the stream is crowded into a narrower channel, and new currents and eddies developed, the changed velocity and the new surfaces exposed to the stream may be the source of considerable trouble if precautionary measures are not taken.

When a new channel or a revised channel is necessary, abrupt changes in the alignment and grade should be avoided; the bed and banks should be reasonably smooth, and the cross-section should be as uniform as conditions permit. The grade line will usually be controlled by ground conditions but preferably should be the minimum required for satisfactory drainage.

Occasionally, adequate protection can be provided only through the use of such special construction features as lining, riprapping, cribbing, retaining walls, check dams and vegetation.

NOW ANSWER THESE QUESTIONS

1. What is meant by erosion in a stream channel?

2. Why is it advisable to construct a culvert in line with a long-existed stream channel?

3. What can happen if the alignment or grade of a channel is abruptly changed?

4. What should be considered when a new or revised channel is necessary?

5. What are some other methods by which erosion can be prevented in a channel change?

PAVED DITCHES

Paved Ditches are used when high velocities cannot be avoided. They may consist of Portland Cement or Bituminous Concrete, or of rubble with dry or grout-filled joints, If the volume of water is sufficient, a storm sewer can be placed in the ditch line with frequent grating inlets.

On some highway fills, a paved or surface ditch is constructed along the shoulder. Inlets admit water to pipe spillways or flumes leading along the shoulder. A specially designed metal inlet or "embankment protector" has been used with much success. Inlets may also consist of wooden boxes for temporary use or of concrete or metal corrugated pipe.

NOW ANSWER THESE QUESTIONS

1. When are paved ditches required?

2. What are some paving materials used in ditches?

3. When may a storm sewer be placed in a ditch line?

4. What is used along the shoulder for drainage in many fill areas?

5. What types of inlets are used in such cases?

IRRIGATION DITCHES

Usually irrigation ditches have such slight fall and are so tightly restricted with regard to flowline elevations, alignment and location that very little change can be made in them. If a change is necessary, extreme care must be used to make sure that no loss of water or obstruction to flow will result. If a circular pipe is used to carry the water in a rectangular or trapezoidal shaped ditch and the flowline of the pipe is at the flowline of the ditch, the flow of the water will be obstructed because the bottom part of the pipe is narrower than the ditch. To overcome this, the pipe should be set low enough so that its width at ditch level will more nearly equal the width of the bottom of the ditch. The use of elliptical or arched pipe rather than circular pipe will be advantageous in some cases as it provides greater width at the bottom and at the same time requires less headroom. If a ditch is relocated in material which is not impervious and scour resistant, it may be necessary to line the ditch to prevent loss by seepage and washouts.

NOW ANSWER THESE QUESTIONS

1. What are some of the restrictions connected with irrigation ditches?

2. Why must care be taken in changing the direction of an irrigation ditch?

3. If circular pipe is set in a rectangular or trapezoidal ditch, what precautions must be taken?

4. Show by sketches the difference between circular, elliptical and arched pipe.

5. When and why should a ditch be lined?

LINING

For large streams, the cost of lining the entire channel will probably be prohibitive unless no other measures will suffice. Small streams will generally not require such construction.

Excavation for Structures and Underdrains: The excavation for a structure should be adequate to accommodate the structure to be built and should provide sufficient working space and room for forms and bracing if required.

Economy will generally dictate that the excavation be the minimum necessary but this is usually desirable for stability also because the undisturbed natural ground under and at the sides of the structure itself will ordinarily furnish better support for the structure itself and the embankment to be constructed over it, than will backfill which may be placed instead.

The width of a trench for an underdrain should be ordinarily the minimum which is practicable to dig. The types of trenching machines used in underdrain construction usually dig a trench from 15 to 24 inches wide; if dug by hand labor, the trench must have a minimum width of 16 inches as a man cannot work efficiently in a narrower width. A trench may be dug with vertical sides in stiff clay or other stable earth but in most other types of material will have to be given a batter to counteract the tendency to cave in.

Excavation for small culverts is usually performed by hand labor but for larger structures mechanized methods are preferable. As in the case of open channels and ditches, it is often more economical to use power shovels, draglines or tractors with their attachments to do the digging even

though a much larger excavation is required for efficient operation than the minimum which would be necessary if hand methods were used.

The excavated material should be cast well back from the edge of the excavation so that it will not slough back in and so the weight of the loose earth will not cause the bank to cave. Large stones and boulders may be encountered in trench excavation which are too hard to break conveniently by sledging and conditions may not permit blasting. They can be moved out of the way by rolling them into holes dug in the sides of the trench for the purpose of receiving them.

NOW ANSWER THESE QUESTIONS

1. Why is the lining of large stream channels not practical?

2. What principles do you follow in the amount of excavation for a drainage structure?

3. What is the rule of thumb for the width of a trench for pipe underdrain?

4. What is the usual method of excavating for small culverts?

5. What should be done with material excavated for a drainage structure?

DEBRIS CONTROL DEVICES

Streams frequently carry with them, either floating or rolling along the bottom, considerable quantities of debris ranging from leaves, weeds and small twigs to large logs or boulders. Some provision should be made at or near the culvert entrance to reduce the interference of such debris with the satisfactory operation of the structures. The control device may be a V-shaped barrier of steel, timber or concrete piling or cribbing to deflect large logs or boulders away from the culvert entrance and into basins at the sides. If basins to receive deflected debris are not practicable, a similar barrier may be constructed straight across the channel to catch and hold the debris. For small structures the best barrier will usually be a grating or grillwork of steel or timber constructed directly across the culvert entrance. The spacing of the barrier members should be such that nothing will pass larger than the culvert can handle. The barrier should preferably be high enough to prevent the water and floating debris going over the top even when the water level is raised because of the obstruction of the lower portion of the barrier by debris.

NOW ANSWER THESE QUESTIONS

1. What type of debris may be encountered in the normal flow of a stream?

2. Name several ways of controlling the interference of debris.

3. What is the best barrier for small drainage structures?

4. How high should such a barrier be?

STAY BRACING, SHEETING AND SHEET PILING

When trenches for underdrains or excavation for structures must be dug in unstable ground, it may be more economical to make use of stay bracing, sheeting or sheet piling than to excavate the material back to slopes which will stand unsupported. Stay bracing and sheeting are used when the supports for the sides of the excavation can be placed after the excavation has been completed roughly. Sheet piling is used when the ground is so unstable that the supports must be driven into the undisturbed ground to hold it in place while the excavating is being done. Sheet piling is also used to prevent water from seeping or flowing into the excavation.

Stay bracing consists in merely placing planks of random dimensions against the side of the excavation and bracing them against the opposite side of the excavation. The planks may be placed either horizontally or vertically and may be intermittent as to location, being used only where needed to prevent the caving in of large masses of earth and boulders.

Sheeting is similar to stay bracing except that instead of the planks being of random dimensions and placed in random locations where needed, they are of uniform size and are placed in systematic manner continuously over large sections. The planks may be placed against the bank either vertically or horizontally. Vertical planks are held in place by long horizontal timbers called rangers which are braced against corresponding rangers on the opposite side of the excavation. Horizontal sheeting is held in place by vertical timbers similarly braced. Sheeting may be of the closed type in which the planks are placed tightly against

one another to cover the entire surface to be supported or may be of the skeleton type in which the planks are rather widely spaced.

Sheet piling consists of timber planks or steel members placed behind horizontal timbers called rangers and driven vertically into the ground ahead of the excavation. The rangers are braced against the opposite side of the excavation as in the case of sheeting. When the excavation has reached such depth that support for the sides is necessary the top rangers should be placed in position, preferably 2 or 3 feet below the ground surface. They should then be tacked to two or more temporary sheet piles, driven on the proper line to hold the rangers in place until cross braces have been installed and permanent piles have been driven. The sheet piles should then be arranged in position behind the rangers and driven into place.

Wooden sheet piles should be sharpened at the bottom ends by beveling one side and one edge. The point of the pile should be against the preceding pile in order of driving. This will cause the pile when driven to wedge hard against the last pile driven and form a tight joint. The beveled side of the pile should face toward the inside of the trench. The piles will then tend to drive outward slightly at the bottom, which will insure full width of the trench and at the same time press the upper part tightly against the top ranger. If the piles were placed facing the opposite way, they would tend to drive inward at the bottom and to spread outward at the top pulling away from the rangers.

NOW ANSWER THESE QUESTIONS

1. What is the condition which makes some kind of bracing necessary for

underdrains or excavation for drainage structures?

2. Describe Stay Bracing.

3. Describe Sheeting.

4. Describe Sheet Piling.

SPECIAL PROBLEMS

Side Road Culverts and culverts at farm entrances and in residential areas where side ditches serve instead of curb and gutters, should be placed in the nominal ditch line. They should be amply long to permit an easy turn onto or off the main road. In many locations where the quantity and velocity of water is small, the culvert may be set back from the ditch line and a shorter length be used.

Where good appearance is essential or where a side ditch is hazardous, enclosing the entire ditch in a pipe may cost but a little more and be much more satisfactory than a short culvert or intermittent culverts.

EQUALIZER CULVERTS

These are sometimes installed in low places where there is no channel for the water, but where it is desirable to have the backwater at equal elevations on both sides of the fill. For this purpose, the culvert can be placed at right angles across the road and with a level grade.

RELIEF CULVERTS

On sidehill roads or wherever a road intercepts surface water, it is well to drain the water to the lower side and, if possible, away from the road before it can cause damage. Such relief culverts should generally be placed obliquely across the roadway to give the water more effective inlet and outlet. On long grades, storm sewers may be necessary to prevent overloading of the ditch.

SIPHONS (INVERTED)

These are used to conduct irrigation water under a road where there is insufficient clearance for a culvert. Siphons must be watertight, and can be made so by proper fabrication and joints.

PAVED FORDS

On light-traffic roads and where overflow is infrequent, it is possible to economize on bridges and large culverts by permitting the flood waters to pass directly over a depression in the road. A single or multiple pipe or pipe arch culvert will handle all water except occasional flood flows. To prevent washout, the embankment must be paved, or the roadway protected by means of sheeting or buried steel bin-walls.

NOW ANSWER THESE QUESTIONS

1. Where are "side road culverts" placed?

2. When are "equalizer culverts" used?

3. Describe "relief culverts".

4. When are "inverted siphons" used?

5. Describe the use of a "paved ford".

SECTION II

GENERAL AREAS OF DRAINAGE INSPECTION

CHANGES IN SYSTEM SHOWN ON CONTRACT DRAWINGS

The kinds, sizes, and locations of the parts of the drainage system needed for a particular highway depend a great deal on the actual field conditions. The design office usually plans a proposed drainage system from survey notes long before work is begun on clearing and grubbing. This system is shown on the Contract Drawings. Because of conditions found to exist during construction, however, the system originally designed may not be satisfactory and changes may be needed. The Inspector must keep in mind the importance of good drainage. He should study the drainage conditions from the time he first arrives on the job, before work on clearing and grubbing is started, until the project is completed. If he believes that a change should be made in the system shown on the Contract Drawings, he should bring the matter to the attention of the Assistant District Construction Engineer.

The required size of a culvert for carrying water through an embankment depends on the area, slope, and condition (as cultivated, wooded or grazing land) of the ground from which water runs to the culvert. Filling in a low spot in the ground, even some distance from the highway, may cause an increase in the area of land surface drained by a certain culvert. Or, grading and paving a large area near the culvert, as for a parking lot, may cause the water to run off that area much faster than it did when the drainage system was originally planned. To prevent water from backing up at the culvert and flooding the highway or nearby property, a larger culvert may be needed.

Springs often flow only during certain times of the year or after heavy rains. An underground flow or seepage of water is often discovered for the first time during excavation for the highway, probably after a heavy rain. Quite often, people who live near the project can give an Inspector useful information by telling him about general drainage conditions and high water levels in the neighborhood at certain times of the year.

It is part of the Inspector's job to watch for or find out about any condition that may affect the design of the drainage system and to inform the Inspector. The Inspector should check the information and pass it on to the Assistant District Construction Engineer as soon as possible, so that any necessary changes can be made in the drainage system with the least expense and the least delay to the Contractor.

NOW ANSWER THESE QUESTIONS

1. What determines the kind, size and locations of all parts of a drainage system? Actual Field conditions (Survey [illegible])

2. Where do you find the drainage system needed for a Construction Project?

   Contract Plans

3. What determines the required size of a culvert through an embankment?

   AREA, Slope - [illegible] water runs Before [illegible]

4. What special note must be made of underground springs?

5. What must the Inspector do in order to bring about a change in the drainage system as designed?

LOCATION OF CULVERT

The size, location and grade of each pipe culvert should be exactly as shown on the Contract Drawings, unless field conditions make a change necessary. Although the Inspector does not decide on the proper location of a culvert, he should be familiar with the following principles:

When a culvert is to carry water from a small stream through an embankment, the centerline of the culvert should usually be near the center of the stream and have the same general direction as the stream. Also, the bottom of the culvert should be at about the level of the bed of the stream. A possible reason for moving a culvert from its natural location is the presence of soft material which would have to be removed and replaced with granular material. To find out whether the material of the stream bed is firm or soft, a steel reinforcing bar at least 6 feet long should be driven into the bed in several places.

If a change in the location of a culvert is made for any reason, natural drainage channels should be used wherever possible. Changing the course of a stream may result in a claim for damages by a property owner, either because more water flows onto the property or because some water is drained away from the property.

Before a road is built, water flowing over the ground during and after a rain or when snow melts will follow certain natural drainage channels in the ground. These channels will pass through the low points in the surface. When an embankment is built across a natural drainage channel, water from rain or melting snow will collect at the embankment unless it can flow through the embankment. For this reason, it is usually necessary to provide

a culvert through an embankment at every natural drainage channel.

Where the ground along an embankment slopes in the same direction for a great distance, culverts should be provided through the embankment at suitable intervals. Such culverts are sometimes called drainage relief culverts.

A culvert that is not at right angles to the centerline of the road is said to be on a skew.

The line on the centerline of a pipe in the lowest part of its inside surface is called the flow line of the pipe, and the grade of a pipe is the grade of its flow line. Also, the lower part of the inner surface of a pipe is often called the invert of the pipe.

The grade of a pipe culvert preferably should be at least 1.5 percent, in order that any soil which gets into the pipe will be washed out by the flowing water. The grade should not be greater than about 6 percent because the water would then run through the pipe at such high speed that it may carry with it gravel or fairly large stones which would wear away the invert of the pipe. Paved inverts may be used on steeper grades.

The top of a pipe culvert must be far enough below the surface of the pavement to permit the base and subbase to have the proper thicknesses and also to allow room for a cover of embankment material between the top of the pipe and the surface of the subgrade. During construction, the pipe may have to support the loads from heavy earth-moving equipment without protection from any material above the surface of the subgrade.

NOW ANSWER THESE QUESTIONS

1. Does the Inspector decide on the proper location or change of a culvert?

2. What is a possible reason for moving a culvert?

3. What is a common result of changing the course of a stream?

4. What happens when an embankment is built across a natural drainage channel?

5. Describe the "flow line" of a pipe.

6. How far below the surface of the pavement must the top of a pipe culvert be?

MATERIALS FOR PIPE CULVERTS

The openings in culverts may have different shapes. However, round pipes are used most often for culverts, and only pipe culverts will be discussed in this section. The possible kinds of pipe culverts are as follows:

1) Cast-iron pipe, heavy cast-iron pipe, or extra heavy cast-iron pipe.

2) Reinforced cement concrete pipe or extra strength reinforced cement concrete pipe.

3) Vitrified clay lined reinforced cement concrete pipe or extra strength vitrified clay lined reinforced cement concrete pipe.

4) Corrugated metal pipe.

5) Asphalt coated corrugated metal pipe.

6) Vitrified clay pipe or extra strength vitrified clay pipe.

7) Plain cement concrete pipe or extra strength plain cement concrete pipe.

The kind of pipe to be used for any culvert is shown on the Drawings. The best kind for a particular culvert depends on many things, such as the cost, the pressure on the pipe from the soil, the danger of being eaten away by acid in the water flowing through the pipe, and the danger of being worn away by sand or gravel carried by the water.

The Inspector must make sure that the kind and size of the pipe delivered to each culvert location are the same as those called for by the Special Provisions of the Proposal and the Contract Drawings. If a piece of pipe of a different kind or size is received, it cannot be used without

the written permission of the Assistant District Construction Engineer.

NOW ANSWER THESE QUESTIONS

1. List seven possible types of pipe culverts.

2. Where do you find the type of pipe to be used for a particular culvert?

3. What determines the best kind of pipe for a particular culvert?

4. Whose responsibility is it to make sure that the proper pipe is delivered for a particular culvert?

5. If the wrong type of pipe is delivered, what must be done before it is used?

FIELD INSPECTION OF CULVERT PIPE

Culvert pipe must be furnished by a producer who is on the approved list of the Department. A producer may be placed on the approved list after a Department representative has inspected his plant and found by testing that he will be able to manufacture pipe meeting all requirements of the Specifications. He will receive a copy of a letter given to the Contractor by the District Office to show that the supplier has been approved. The records kept in the field office should include a copy of the report of the Department Laboratory showing that the pipe shipped is acceptable and can be used if in good condition.

The pipe in each shipment should be stamped or marked in some way to show that it comes from a lot which has been inspected and approved at the source. As soon as pipe is unloaded at the job, it should be inspected for any defects that can be seen. Also, the Inspector should check the thickness of cast iron, concrete, or clay pipe with calipers, and should check the gage of corrugated pipe with a micrometer. Culvert pipe must meet all requirements of the Specifications when it is placed in the trench. Another method of checking corrugated metal pipe for correct gage is by weighing a measured length of pipe. Minimum weights per foot of length are given in the Specifications.

The gage of the galvanized metal used in making corrugated metal pipe is based on the weight of the coated metal in ounces per square foot. Gages, weights and approximate thicknesses, for field-checking purposes, are shown in the following table:

GAGE AND THICKNESS OF GALVANIZED SHEET

GAGE NO.	WEIGHT OF** SHEET	APPROXIMATE THICKNESS OF SHEET IN INCHES	TOLERANCE (PLUS OR MINUS) IN INCHES
8	112.5	0.168	0.008
10	92.5	0.138	0.007
12	72.5	0.108	0.005
14	52.5	0.078	0.004
16	42.5	0.064	0.003

** In Ounces Per Square Foot

If a piece of corrugated metal pipe has spots where the zinc coating has been damaged or burned by flame cutting or welding, the piece should not be used. If asphalt coated pipe has spots where the asphalt coating has been damaged, repairs may be made by coating each spot with asphaltic material furnished by the maker of the pipe for that purpose.

NOW ANSWER THESE QUESTIONS

1. How does a pipe producer get on the Department's approved list?

2. What inspections should be made when pipe is unloaded at the job?

3. How is the gage of galvanized metal used in making corrugated metal pipe determined?

4. What is the required weight per square foot of 12 gage galvanized sheet, and its thickness in inches?

5. How may asphalt coated pipe be repaired at the job if the asphalt coating has been damaged?

HANDLING CULVERT PIPE

The Inspector should see to it that culvert pipe is handled properly. If the Contractor uses a method which may damage the pipe so that it will not meet the requirements of the Specifications, he should be warned by the Inspector.

Pipe should always be lowered, not dumped or dropped, from a truck to the ground, or from the ground surface to the bottom of a trench. It may be lowered by using any type of crane or a trench tripod with an "A" frame on one side and a single leg on the other side. When a crane is used for lowering the pipe into a trench, the pipe can be set in position in the trench most easily if a hairpin-shaped hook is inserted in one end of each piece of pipe.

Pipe should be rolled, not dragged, from one place to another. If concrete or clay pipe must be moved over rocky or stony ground, it should be rolled on planks lain on the ground so that the pipe will not be damaged. Although not required by the Specifications, it is good practice to store sections of asphalt coated pipe on planks or timbers so that dirt and small stones will not be pressed into the coating. Each section of pipe with a paved invert should be turned so that the paving is down. In hot weather, sections of asphalt coated pipe should be stored in a shady place, or covered with light colored tarpaulins, so that heat from the sun will not cause the asphalt coating to flow out of place.

NOW ANSWER THESE QUESTIONS

1. How should pipe be removed from a truck to the ground?

2. How should concrete or clay pipe be moved across the ground?

3. What is the best way to store sections of asphalt coated pipe?

4. How does hot weather affect the storage of some pipe?

5. What is a good method of lowering pipe into a trench when a crane is used?

TRENCH FOR CULVERT PIPE

Every pipe culvert must be laid in a trench. Pipe must never be laid on the ground and material piled against and over them. The width of the trench cannot be less than that required by the Specifications, and the trench must be deep enough so that the top of the pipe will be sufficiently protected. Where the pipe is to be placed far enough below the natural ground surface, all of the trench may be dug in the natural ground. If the top of the pipe will be above the natural ground surface, embankment material must be placed and fully compacted to the specified level at which the top of the pipe will be before digging of the trench is begun.

The reason for placing culvert pipe in a trench is as follows: Every pipe culvert especially one of corrugated metal, depends on the support provided by the pressure of compacted soil against the sides of the pipe to help it carry the loads that come on its top. When a pipe is laid in a trench dug in compacted ground or embankment material, and the space in the trench on each side of the pipe is filled with compacted soil, the resistance of the pipe to crushing is greatly increased. A trench should not be wider than necessary to allow room for compacting the soil around the lower half (haunches) of the pipe, because making the trench wider increases the load of the pipe. The classification of excavation for a culvert is shown on Sheets E-5 and SD-14 of the Standard Drawings.

When the depth of a trench is more than about 4 feet, the sides of the trench may need to be braced in some way, especially if heavy construction equipment will be operated near the trench or if material thrown out of the trench is piled up on one side of it. A man can easily be killed

if one side of a trench slides or caves in while he is in the trench. The Inspector should see to it that the Contractor complies with the safety regulations of the Pennsylvania Department of Labor and Industry in regard to bracing of trenches.

NOW ANSWER THESE QUESTIONS

1. What determines the width of a trench for pipe culvert?

2. How does soil compacted around the sides of a pipe benefit the pipe?

3. What is meant by the "haunches" of a pipe?

4. Where would you find the classification of excavation for a culvert?

5. Why is bracing needed in a deep trench?

SHAPING TRENCH BOTTOM

A pipe culvert must be properly bedded on a firm foundation. It is not good enough to have the bottom of the trench smooth and flat and on the proper grade. The bottom of the trench for some distance on each side of the pipe centerline must be shaped to fit the curve of the pipe. Also, when bell-and-spigot pipe is used, holes must be dug so that the bells do not touch the trench bottom.

The pipe must be supported uniformly. To be satisfactory, the trench bottom must have no hard places or soft places. The best material on which to lay pipe is sand of fine soil that has been well compacted.

Small pockets of unstable material in the bottom of the trench should be removed and replaced with good material. If the natural material in the bottom of the trench will provide good support for the pipe, Class C bedding can be used. Corrugated metal pipe should usually be bedded for 15 percent of its outside diameter. If the material at the bottom of the trench is very soft, the pipe may have to be bedded in a concrete cradle. Where there is rock at the bottom of the trench, a suitable bed for the pipe must be provided by removing the rock from below the pipe and replacing it with a cushion of granular material which is well compacted. If there are many large stones at the bottom of the trench, the Contractor may prefer to make the trench deeper and refill the lower part with fine material that can be easily brought to grade.

NOW ANSWER THESE QUESTIONS

1. What are the requirements of a good trench bottom?

2. What is the best material on which to lay pipe?

3. How should corrugated metal pipe be bedded?

4. What must be done if the natural material at the bottom of the trench is very soft?

5. Rock is excellent material for the bottom of a trench. Comment on this statement.

LAYING CULVERT PIPE

When culvert pipe is to be placed in the trench, it should be lowered in some proper way. Cement concrete pipe or vitrified clay pipe can be easily damaged if it is dropped. If corrugated metal pipe is dropped dents may be made in some of the ridges, or some of the zinc spelter used for galvanizing the steel or some of the asphalt coating may be knocked off. When the protective coating is damaged, the steel in the pipe will rust very quickly. If asphalt coating is knocked off a small area, the bare metal at that place must be painted with asphalt furnished for the purpose by the manufacturer of the pipe. The manufacturer's directions for applying the asphalt must be followed.

If the pipe is not heavy and the trench is narrow, a rope may be passed through the pipe and it may be lowered slowly by two men who straddle the trench and pay out the rope. A crane should be used for lowering large pipe. Each piece of pipe may be supported by a hairpin-shaped hook inserted in one end, or it may have lifting holes, or eyes, for connecting a crane hook to it.

Before a piece of bell-and-spigot pipe is lowered into the trench, it should be turned so that any small defects are at the top. Paved pipe should be laid with the paving material at the bottom. If reinforced cement concrete pipe is oval in shape, a mark labeled "top" must be uppermost. Corrugated metal pipe should be turned so that the lengthwise lap is at one side. This lap should never be at the top or bottom.

Pipe laying should be started at the outlet end of the trench. Corrugated metal pipe should be laid with the inside laps pointing downstream. Such laps are joints formed in the pipe when pieces are connected at the manufacturing plant. Bell-and-spigot pipe must be bedded with the bell end upstream. First, a small hole must be dug in the bottom of the trench directly beneath the bell to free it from the bottom in order that the weight of the pipe will be on the barrel. The inside of the bell of the piece of pipe last laid should be cleaned with a wet brush, and the lower half of this surface should be covered with freshly mixed 1:2 cement mortar. The mortar should be as wet as possible and still not sag. The entire spigot end of the piece of pipe to be laid next should be cleaned with a wet brush and forced inside the bell so that mortar is squeezed out of the joint. The position of the centerline of the pipe must then be checked with a plumb bob, and the grade of the flow line must be tested with a grade stick. A metal shoe on the bottom of the grade stick will extend into the pipe. If the pipe is a little off line, it may be straightened. If the flow line is not at the proper grade, however, the piece of pipe being set must be taken out of the bell, and the bed brought to the correct grade and shape. Fresh mortar must be put in the bell before the pipe is reset.

To make strong joints in the bell-and-spigot pipe, each spigot must be forced as close as possible to the inside of the bell of the piece previously laid. In small pipe, with either bell-and-spigot joints or tongue-and-groove joints, a good joint can be made by hand if a pipe buck is used. A pipe buck resembles a wheelbarrow. A small wheel at one end of the buck runs on the bottom of the piece of pipe laid. The weight of the piece of pipe being laid is carried by the saddle on the buck when its handle is lifted up. The pipe can be pushed tightly into place with little force. Large pipe usually has tongue-and-groove joints. To get a tight joint in large pipe, the pieces

of pipe must be pulled together with a hand winch in the following way: A piece of timber a little longer than the inside of the pipe is jammed, in a slanting position, into a piece of pipe already laid as shown in the picture. The hand winch is anchored to the bottom end of this timber by a cable, and a rope or cable leading from the winch is fastened to a timber placed across the end of the pipe being laid. By use of the winch, the new piece of pipe is pulled tightly into position.

<u>NOW ANSWER THESE QUESTIONS</u>

1. Give some approved methods of lowering pipe into a trench.

2. Where should pipe-laying be started in any trench?

3. Describe how bell-and-spigot pipe is bedded.

4. Describe a pipe-buck and what it is used for.

5. How is a hand winch used in laying pipe?

FINISHING JOINTS IN PIPE CULVERT

The inside of a pipe culvert must be smooth and even at each joint. Any space left between the pieces of pipe at a joint should be filled with mortar, and the joint wiped flush with the surface. When the diameter of the pipe is small, this work can be done with a burlap swab on the end of a pole long enough to reach back to the joint.

The outside part of either a tongue-and-groove joint or a bell-and-spigot joint must be filled with mortar that is trowelled to form a smooth bead. On bell-and-spigot pipe, the exposed surface of a bead should have the same shape as the corresponding part of the other side of the bell.

Beading should be done four or five pipe lengths behind the joint being made in order that the beads will not be knocked loose. The outside of the pipe next to the joint should be cleaned all the way around with a wet brush before the joint is filled and the bead made. If the bead sags at the bottom, fine soil may be packed under it to provide temporary support until it hardens. The beads must be cured in the usual way.

Lifting holes in pipe should be plugged with wooden plugs and covered with mortar at the time the beads are made. This mortar must be cured in the same way as the beads.

NOW ANSWER THESE QUESTIONS

1. What must be done with open spaces at the joint of two pieces of pipe?

2. How is the outside part of a tongue-and-groove or bell-and-spigot joint treated?

3. How is beading done on several lengths of pipe?

4. What is done when the bead sags at the bottom?

5. What treatment is given to pipes equipped with lifting holes?

MORTAR FOR JOINTS IN PIPE

Two kinds of mortar are needed for the joints in a pipe culvert. One kind, which is fairly soft, is used before the new piece of pipe is laid. The other kind, which is much stiffer, is used for filling the joint from the outside and making the bead. This mortar must be stiff enough to permit the bead to be made all the way around the pipe without having the part at the bottom sag away from the pipe. Mortar should be freshly mixed in small batches. If mortar is allowed to stand more than about 30 minutes and starts to set, it should be thrown away. Old mortar must never be softened by mixing in more water, as it will not have full strength when it hardens.

Like any other portland-cement mixture, the mortar used in joints in pipe must be cured properly. If it is allowed to dry out too quickly, it will not be strong enough after it hardens. As soon as the bead has been formed around the joint, the joint should be covered with a strip of wet burlap which is folded to make several thicknesses, which should be kept wet for 48 hours.

A mortar joint must never be made under water. Also, running water must be kept away from a freshly made joint for at least 24 hours. Sometimes a trench can be kept fairly dry by letting the water flow along the sides of the trench to sumps from which it can be pumped. When there is a lot of water, the trench can be made deeper and the lower part can be refilled with about 2 feet of gravel and a covering layer of bedding material. Pumping from temporary wellpoints in the gravel will keep the water down.

NOW ANSWER THESE QUESTIONS

1. What are the two types of mortar used in pipe joints and how are they used?

2. How should mortar for pipe joints be mixed?

3. How is mortar in pipe joints cured?

4. How long should the freshly made joint be kept free from running water?

5. Describe some methods of keeping the trench dry.

CONSTRUCTION OF CONCRETE CRADLE

There are two good ways of placing the concrete in a cradle under a pipe culvert after the trench has been dug to the level of the bottom of the cradle. In one method, the pipe is set to its final line and grade before the concrete for the cradle is poured into the trench. The pipe may be supported in position on blocks of wood or precast concrete laid on the trench bottom; or stakes may be driven into the trench bottom near the sides of the trench, and 2 x 4 boards nailed to the stakes with their tops at the level of the bottom of the pipe.

When the pipe is put in position before the concrete for the cradle is placed, the concrete must be very wet because it must be compacted under the pipe by spading and rodding. The cradle should extend above the bottom of the pipe for a height equal to one-fourth of the outside diameter of the pipe. In order that the pipe will not be forced out of position while the cradle is being case, the concrete must be poured carefully on both sides of the pipe at the same time. If too much concrete is poured in one place, the pipe will float.

The other method of providing a concrete cradle under a pipe is as follows: The part of the cradle below the lowest point on the pipe is made of dry concrete. This concrete is placed before the pipe is put in the trench, and the surface of the concrete is brought accurately to the grade for the bottom of the pipe. If bell-and-spigot pipe is used, the concrete surface should be at the grade of the line through the bottoms

of the bells. After the concrete below the pipe has become hard enough to be worked on, the pipe should be laid in its correct position on this concrete. Looped wires may be placed in the concrete before it hardens and later used to tie the pipe in position. Then wet concrete is used to complete the cradle.

NOW ANSWER THESE QUESTIONS

1. Describe two ways of placing a concrete cradle under a pipe culvert.

Support the pipe on blocks or precast concrete & pour concrete in from each side at the same time - with dry concret first before pipe is [illegible] then wet concret placed

2. How high should the cradle extend above the bottom of a pipe?

1/4 of the outside diameter of pipe

3. What should be done with corrugated pipe before a concrete cradle is poured? - set to grade all bands put on & tightened

USE OF BATTER BOARDS FOR PIPE CULVERT

Where the trench for a pipe culvert is short, batter boards need be set only at its ends. If the trench is quite long, batter boards should be set about 25 feet apart to cover its entire length. The trench should be dug nearly to its full depth before the batter boards are set. The batter boards should be so placed that each board is about at the same distance above the final elevation of the flow line of the pipe and is higher than the top of the pipe when it is in its final position so that it will not interfere with the laying of the pipe.

To set a batter board, a stake is driven firmly into the ground on each side of the trench. The batter board is now held across the trench so it is about level and is nailed to the stakes. A surveying instrument is used to locate the centerline of the trench on each batter board. A target board is then nailed to each batter board so that one edge is at the centerline and is exactly vertical as shown by a plumb bob. A nail is driven into this edge of the target board at a predetermined distance above the flow line of the pipe. A stringline can then be stretched tightly between the nails for use in grading the ditch and laying the pipe to line and grade. (See the batter board on the cover of this Manual)

Another method of setting batter boards is to drive metal stakes on 25-foot spacing on both sides of the trench. Each batter board can be clamped to opposite stakes with the top edge at a definite distance above the flow line of the pipe, and a nail can be driven into the board at the centerline of the trench to hold a stringline.

The workman who is fine grading the trench should be given a grade stick. This stick should have a nail driven into it at a distance from its

lower end equal to the distance from the stringline to the flow line of the pipe plus the thickness of the pipe shell. The point in the bottom of the trench directly under the stringline, which is at the centerline of the trench, should be brought to the proper grade by measuring vertically downward from the line with the grade stick. Grading should start at the outlet end of the trench, in order that any water in the trench will drain out.

NOW ANSWER THESE QUESTIONS

1. Describe a batter board and its use. ITS A BOARD SET ACROSS A pipe TRENCH USED FOR FINE GRADING BOTTOM OF TRENCH & LAYING pipe + CHECK GRADE + ℄ OF PIPE

2. How often are batter boards placed over a long trench? 25'

3. Describe a grade stick and its use. USED FOR FINE GRADING TRENCH & MEASURE DISTANCE FROM STRINGLINE TO FLOW LINE of pipe plus THE THICKNESS of pipe SHELL

4. At what end of the trench should grading start? OUTLET END

PLACING BACKFILL IN TRENCH

Making sure that the Contractor does a good job when compacting backfill around a pipe culvert is one of the hardest jobs of an Inspector. Proper compaction of the backfill is very important for two reasons. One is that well compacted material under the lower half, or haunches, of the pipe and between the pipe and the walls of the trench helps to keep the pipe from being crushed by the loads on its upper part. Also, poor compacted backfill will always settle, and there will be a low spot in the road above it.

Before any pipe is laid in a trench, the Inspector should have a clear understanding with the Contractor in regard to the methods, materials, and equipment that are to be used in the backfilling operations. Any disagreements should be referred to the Assistant District Construction Engineer. When all the details have been approved, the Inspector must see to it that each of his Inspectors knows how the job is to be done and that the Contractor has given his foremen and workmen the proper instructions.

Backfill material must never be bulldozed or dumped into the trench. It must be shoveled into the trench from a spoil bank or from piles located at least 3 feet from the edge of the trench. Large lumps or large stones must be removed from material that is thrown into the trench around the pipe. The backfill must be brought up slowly and evenly on both sides of the pipe. It is most practical to compact the backfill as it is being placed, instead of placing the material in definite layers and compacting each layer, but if the backfill is placed in layers or lifts, the depth of a lift must not be more than 4 inches.

Most of the work for compacting the material under the haunches of the pipe must be done with hand tools, since mechanical tampers will not

usually reach this space. Hand tampers or short pieces of timber may be used. One man shoveling to two men tamping is about right for this work. The backfill between the pipe and the sides of the trench and around the upper half of the pipe should be compacted with power tampers. There should not be more than two shovelers for each power tamper.

The soil used for backfill should be moist enough to pack well. If the soil is too dry, water must be added by sprinkling it on the spoil bank and mixing it in before the soil is thrown into the trench. A rough test can be made by squeezing the soil in the hand. It should make a firm cast which will not break up when handled or tossed in the air. Fully compacted material will usually "ring" under the blows of a power tamper. If deep dents remain in the soil after it has been tamped, the soil is probably too wet. Dry soil should then be mixed with the material in the spoil bank. Bracing and sheeting must be raised or removed as the trench is filled, but enough must always be left in place to keep the trench safe.

If uprights are left in place until after backfilling, the spaces left when they are puleed should be filled with dry sand. The sand should be pushed and compacted, with a piece of board, into the hole left by removing the uprights or sheeting. In most cases, the backfill in the trench and embankment material over the trench should be compacted up to subgrade level. However, when the culvert is to be covered with a high fill, the Specifications require that a special method, called the imperfect trench method, be used to protect a rigid pipe from the weight of the fill.

In such a case, after the backfill has been compacted up to one foot above the top of the pipe, the embankment shall be constructed to an elevation equal to the diameter of the pipe plus one foot. Next a trench is excavated to a width equal to the outside diameter of the pipe and to a

depth of one foot above the top of the pipe. Care shall be taken so that the sides of this trench are as vertical as possible. The material for the cushion should be shoveled into the trench from both sides, so that it will have nearly uniform density. After the cusion has been brought up evenly to the required level, the rest of the material in the trench or in the embankment over the trench must be fully compacted. When the backfill is placed in this way, the compacted material over the cushion carries the load from the fill above it to the sides of the trench by arch action, like that in an arch bridge of masonry. This arch action takes a great deal of the load off the pipe and helps prevent the pipe from being crushed. Also, if the backfill above the cushion is fully compacted, especially next to the sides of the trench, there will be no settlement of the road, because the "plug" of compacted material will key into the sides of the trench.

Special care must be taken in placing backfill material around elongated corrugated metal pipe. Selected material must be used up to a level of at least 12 inches above the middle of the height of the pipe. This backfill should be placed in uniform lifts not more than 4 inches deep. It must be firmly tamped under the pipe and along both sides. If the haunches of the pipe are not supported properly, the vertical diameter of the pipe will be short when the embankment is completed. The rest of the backfill may be placed as described for culvert pipe that has not been elongated.

NOW ANSWER THESE QUESTIONS

1. What are two important reasons for compacting backfill in a trench?

Keep pipe From Being crushed
stop settling of Road over pipe

2. What should the Inspector discuss with the Contractor before backfill is placed? METHOD, MATERIALS & Equipment TO Be used

3. How should backfill material be placed in a trench? Never Be Bulldozed or Dumped, IT MUST Be Shoved in From piles 3' From Trench

4. How is most of the work of compacting backfill around the haunches of the pipe done? WITH HAND TOOLS

5. Describe the "imperfect trench" method for placing backfill. Fill Trench TO 1' over pipe plus compaction THEN Embankment TO Elev. of THE DIAMETER of Pipe + ONE FOOT THEN dug out THE WIDTH of pipe TO WITHIN ONE FOOT of pipe - THEN PUT IN MATERIAL IN for CUSHION

6. How is backfill placed around elongated corrugated pipe?

Selected MATERIAL USED TO 1' Above Middle of THE Height of pipe

OUTLETS AND INLETS OF PIPE CULVERTS

The outlet of a pipe culvert should be set as high as possible in order to reduce the required amount of excavation for a ditch to carry the water away from the culvert, and to lower the cost of keeping the outlet clear. A pipe culvert should extend between 1 and 2 feet beyond the toe of the embankment at its outlet end. The water coming out of a culvert may flow down a paved slope of the embankment or into a spillway, or may fall onto rock. In flat country, it may be necessary to let the water from a culvert flow into an underground watercourse or, if there is no better way, into a sump.

The inlet end of a pipe culvert must be placed far enough back of the edge of the roadway shoulder so that an endwall or a drop inlet can be built. When a ditch running parallel to the roadway is needed to lead the water to a culvert there should be a space at least 2 feet wide between the ditch and the outside edge of the shoulder. The flow line or invert of a culvert should be set low enough to carry away surface water without danger of flooding of nearby land, and to allow the water from any underdrains that are supposed to empty into the culvert to flow into the invert without danger of water backing up into the drain when the culvert is running full. However, the flow line should not be low enough to cause silting of the pipe.

NOW ANSWER THESE QUESTIONS

1. Why should the outlet of a pipe culvert be placed as high as possible?

Reduce The Required Amount of Excavation

2. How far should a pipe culvert extend beyond the toe of the embankment at its outlet end? 1 & 2 Feet Beyond Toe

3. How far back of the edge of the roadway shoulder should the inlet end of a pipe be placed? So you can Build Endwalls or A Drop inlet

4. How low should the flow line of a culvert be placed? To carry Away surface water without danger of flooding nearby land

5. What happens when the flow line is placed too low? will cause silting of pipe

CAMBER OF CULVERT PIPE

When a pipe culvert is placed in a high embankment, the load on the top of the culvert is much greater between the roadway shoulders than near the ends of the pipe. If the pipe were laid on a straight grade, there would be a tendency for it to settle more in the central part, as shown in the picture, and its capacity for carrying water would be greatly reduced. To allow for unequal settlement, the pipe should be laid originally so that its flow line is 1 to 3 inches above the straightline grade at the centerline of the roadway, and the height above the straightline grade should be gradually reduced to zero at each end of the pipe. This raising of the pipe is called cambering.

An easy way of providing camber in a pipe is as follows: After the batter boards and target boards have been set, marks on the target boards are first made at a uniform distance above the straightline grade. Then, a stringline is stretched tightly between nails driven in the end target boards, at the marks, and the center of the line is lifted to give the desired camber. Nails are driven at stringline grade in all target boards between the end target boards, stringlines are stretched between the nails, and the grade stick is used for measuring the proper uniform distance from the stringline to the bottom of the trench.

NOW ANSWER THESE QUESTIONS

1. Describe "camber" in a culvert pipe. HAVING THE PIPE RAISED 1" TO 3" AT THE CENTER LINE OF ROADWAY

2. Describe an easy way of providing camber in a pipe. SET BATTER BOARDS & TARGET BOARDS FIRST - THEN MARKS ON TARGET BOARD ARE MADE ABOVE STRINGLINE GRADE, THEN STRETCH A STRINGLINE TIGHTLY THEN LIFT CENTER OF STRINGLINE TO DESIRED CAMBER

OTHER FEATURES IN LAYING PIPE

At the end of each day, the trench with no pipe in it should be blocked off by a temporary dam or tight bulkhead located a short distance beyond the end of the pipe. The end of the pipe should not be blocked, because water filling the trench would then float the pipe and break the joints. Backfill should be compacted around and over corrugated metal pipe as soon as it has been laid, because this type of pipe floats easily and floating will bend and kink the pipe. In case a piece of pipe floats, it must be pulled out. If it has been damaged, it must be rejected.

When a pipe culvert must have a definite length, as between endwalls, and a short piece must be used to obtain the required length, a full length piece should be put at each end of the culvert and the short piece should be the second or third piece from one end.

NOW ANSWER THESE QUESTIONS

1. What must be done at the end of each day to a trench with no pipe in it?

Blocked off By a temporary DAm or tight Bulkhead

2. Why should the end of a pipe not be blocked? — WATer Filling Trench will Float THe pipe

3. How is a short length of pipe placed to complete a required length of culvert? Full Length at EACH END & short piece placed second or third from END.

4. What happens to corrugated metal pipe when it floats? - IT will BEND or KINK

INSPECTION OF PIPE IN PLACE

All pipe must be inspected in place before backfilling is started. Each mortar joint of large pipe should be inspected from inside the pipe to make sure that it is filled. Even if the pipe is fairly small, the joints can be checked from the inside by a man riding on a crawler, like that used by an auto mechanic to get under a car. The crawler is pulled through the pipe with a rope.

The bead on the outside of each mortar joint should also be checked after the entire culvert has been laid. Any weak or cracked mortar should be chipped out and replaced. Any piece of pipe that has been dented, cracked, or broken will have to be taken out and replaced, unless repairs that are satisfactory to the Assistant District Construction Engineer can be made without removing the piece.

NOW ANSWER THESE QUESTIONS

1. What must be inspected when pipe is in place? EACH MOTAR JOINT FROM THE INSIDE - THE BEAD ON THE OUTSIDE OF EACH MORTAR JOINT

2. Describe the use of a "crawler". USED TO INSPECT THE INSIDE OF PIPE SAME AS USED BY AUTO MECHANIC IT IS pulled BY Rope THROUGH pipe

USES OF PIPE UNDERDRAINS

A pipe underdrain is built by digging a trench, laying a pipe in it, and backfilling it. Type I backfill consists of coarse aggregate in the lower part of the trench and a layer of soil at the top. Type II backfill consists of layers of coarse aggregate, fine aggregate, and soil. A pipe foundation underdrain is built like a pipe underdrain, but no soil backfill is used in the upper part of the trench.

Pipe underdrains or pipe foundation underdrains are used for five general purposes:

1) To drain springs and cut off seepage in the original ground either under an embankment, or along benches where the highway is located on the side of a hill.
2) To lower the surface of ground water so that it will be below the surface of the subgrade.
3) To collect and carry away water that seeps into the subgrade through the road surface or shoulder.
4) To cut off seepage which might cause a slide.
5) To provide an outlet for water that gets into a subbase.

It is the responsibility of the Inspector to look for any condition which may create a drainage problem. If he notices such a condition at any time, he should notify the Assistant District Construction Engineer. Underdrains can then be provided wherever necessary to keep water from being trapped.

After the work of clearing and grubbing has been finished, but before the construction of an embankment is started, the Inspector must inspect the original ground for signs of springs, slides, or seepage. Also, after the benches have been formed on a side-hill location, he must look for any signs

of seepage or any layer of stratum of impervious material, such as fireclay or coal, which may cause seepage during wet weather. He must study ground-water conditions while grading work is in progress and after it has been completed. Whether the water gets into the subgrade from outside the road-way or through the road surface, it must be allowed to escape.

In an area in which slides have already occurred, underdrains seldom help because the ground is usually too broken and has too many openings through which surface water can flow. In order that underdrains may be effective for cutting off springs or seepage above a slide area, all loose material must be taken out before the drains are placed. The drains may have to be put in deep trenches or in horizontal holes bored in the side of a cut.

Since a subbase serves as a continuous drain under a base course or a pavement, an underdrain for carrying away water must be provided on one side or on each side of the roadway wherever the subbase is in a cut.

NOW ANSWER THESE QUESTIONS

1. Describe Type I and Type II backfill. #I CONSISTS of COARSE MATERIAL IN LOWER PART of TRENCH & A LAYER of SOIL AT THE TOP #II A LAYER of COARSE, LAYER of FINES & THEN SOIL

2. What are the five general purposes of pipe underdrains?
TO DRAIN SPRINGS, CUT OFF SEEPAGE &
TO LOWER THE SURFACE of GROUND WATER
TO COLLECT & CARRY AWAY WATER THAT SEEPS INTO SUBGRADE
TO CUT OFF SEEPAGE THAT WOULD CAUSE SLIDES
TO PROVIDE AN OUTLET FOR WATER THAT GET INTO SUBBASE

3. As far as drainage is concerned, what are the things an Inspector must look for after clearing and grubbing is completed? Signs of springs, slides or seepage

4. What happens in areas where slides have already occurred? Underdrains seldom help - Ground all loose & broken up must all be removed first

5. How does subbase for a roadway aid drainage? It serves as a continous drain & a underdrain must be on one side or both in a cut area

CONSTRUCTION OF PIPE UNDERDRAINS

The pipe for a pipe underdrain or a pipe foundation underdrain may be of perforated vitrified clay, cradle-invert vitrified clay, perforated bituminized fiber, porous cement concrete, or perforated corrugated metal. Neither porous cement concrete nor perforated corrugated metal should be used where the pipe may be exposed to acid water. Vitrified clay pipe may be of the bell-and-spigot type or may have plain ends.

After the location and type of underdrain have been selected by the Assistant District Construction Engineer, layout stakes are set by the Contractor and checked by the Inspector. The Contractor must place batter boards at intervals of not more than 25 feet along the line of the drain. They are used in the manner described for pipe culverts.

Perforated vitrified clay pipe or perforated corrugated metal pipe is usually placed with the perforations down. Such pipe must be laid in a straight line and so that the groups of perforations are equally spaced from the lowest point on the centerline of the pipe in its final position. Bell-and-spigot pipe must be centered by mortaring or calking the bottom half of the joint, unless the pipe is made with lugs that will keep the pieces of pipe lined up at the joint. If the vitrified clay pipe has plain ends, approved spring-wire clips or split couplings must be used at the joints. In general, perforated corrugated pipe is preferred for shoulder and lateral drains, because there is less danger of breakage or crushing.

NOW ANSWER THESE QUESTIONS

1. Name five types of pipe used for pipe underdrain.

perforated vitrified clay
cradle-invert vitrified clay
perforated bituminized fiber
porous cement concrete
perforated corrugated metal pipe

2. When should perforated corrugated metal pipe not be used for underdrain?

when exposed to acid water

3. What does the Inspector do before pipe underdrain is placed?

check layout stakes

4. How is perforated pipe placed? with perforations down

5. Why is perforated corrugated pipe preferred for shoulder and lateral drains? less danger of breakage or crushing

PLACING BACKFILL FOR PIPE UNDERDRAIN

Detailed instructions for placing Type I or Type II backfill in the trench for a pipe underdrain are given in the Specifications. Some other type of backfill may be required by the Special Provisions of the Proposal or authorized by the Assistant District Construction Engineer. For example, if a trench for perforated metal pipe is dug in fine-grained soil, the best filter material may be concrete sand or sand-gravel. If a trench for bell-and-spigot vitrified clay pipe is dug in fine-grained soil, it may be best to place a filter material such as crushed stone or gravel next to the pipe and to use concrete sand between the coarse aggregate and the sides of the trench and also above the coarse aggregate. The coarse material prevents the sand from passing through the open joints in the pipe, while the sand allows water to get into the pipe but keeps out the fine particles of soil which could clog the pipe.

Care must be taken to keep dirt out of the filter material while the trench is being filled. One way of keeping the filter clean is by laying a canvas cover over the ground at the top of the trench and over the sides of the trench while the filter backfill is being put in the trench. A better way is to use a plywood or metal form that is about 10 feet long, is open at the top and bottom, and has handles for lifting it out of the trench after the backfill material has passed through it into the trench.

A form is especially useful when coarse filter material such as gravel or crushed stone is to be placed around the pipe, and sand is to be used for filling the rest of the trench. After the bottom of the trench has been shaped and brought to grade and the pipe has been set in the proper position on the bed, the form is put in place so that it rests on the pipe bedding and the pipe is centered in it. Then the coarse filter material for backfill

is dumped into it to the proper level, and sand backfill is placed between the form and the sides of the trench. The form is now lifted out of the backfill and moved down the trench. Finally, sand backfill is used for the whole width of the trench to the required level, and the rest of the trench is filled with compacted soil.

The Contractor may decide to speed the placing of filter backfill by using a transit-mix truck. This method makes it easy to chute the right amount of material directly into the trench.

It is important to prevent surface water from getting into the trench for a pipe underdrain. For this reason, the top of the trench should be sealed with a layer of impervious material, such as clay soil. Surface water not only overloads the underdrain but also tends to wash fine soil particles into the filter material. The surface water should be taken care of by surface drainage.

NOW ANSWER THESE QUESTIONS

1. How would you describe "filter material" in a pipe underdrain structure?

THE TYPE USED AS TO THE MATERIAL WHERE THE ... IS DUG IN FINE SOIL AS TO USE SAND OR SAND GRAVEL

2. Why is it necessary to keep the filter material clean? SO IT CAN FILTER OUT FINE SOIL TO PREVENT clogging of pipe

3. Describe two methods of keeping dirt out of the filter material.

LAY CANVAS over ground A TOP of TRENCH & over SIDES of TRENCH — or use plywood or Metal Forms THAT Are About 10' Long THAT Are open AT Top & Bottom & HANDLES For Lifting

4. What is the usefulness of a form when coarse filter material is used?

when COARSE MATERIAL is used AROUND pipe & SAND is used for filling the Rest of Trench — SAND is Put outside Forms To side of Trench

5. How may surface water be kept from getting into the trench for a pipe underdrain?

The Top of TRENCH is SEALED WITH A LAYER of IMPERVIOUS MATERIALS SUCH AS clay soil

OTHER FEATURES OF PIPE UNDERDRAINS

Even the most carefully built underdrains are likely to become plugged in due time. Plugging is rapid right after the underdrain has been put into use, but proceeds very slowly after about a year. To permit a long underdrain to be cleaned out any time after it has been completed, Y-connections should be set in the pipe line at suitable intervals during construction. The arm of each Y should be in a vertical plane and should point toward the higher end of the drain. A passageway from the ground surface to each Y is provided by a line of pipe of the required length. The top of each such line is plugged until the underdrain is to be cleaned. Then the plugs are removed, and the underdrain is flushed out with water from a hose.

Provision must be made for allowing the water to flow out of a pipe underdrain. The outlet for an underdrain is a pipe placed in a trench which is backfilled with soil. Since the purpose of an underdrain outlet is to carry away the water from the underdrain, and not to collect more ground water, pipe without perforations must be laid with watertight joints. The pipe may be of vitrified clay, plain cement concrete, corrugated metal, or bituminized fiber. The material used should be the same as that of the pipe for the underdrain itself. The procedures for grading and shaping the trench bottom, laying the pipe and placing backfill are described in detail in the Specifications.

NOW ANSWER THESE QUESTIONS

1. What is the critical period for pipe underdrains to become plugged?

RIGHT AFTER UNDERDRAINS ARE PUT IN USE, BUT PROCEED SLOWLY AFTER 4 YEAR

2. What is one method for cleaning out a long underdrain?

Y-CONNECTIONS SHOULD BE SET IN THE LINE AT SUITABLE INTERVALS TO FLUSH OUT LINE

3. What is the purpose of an underdrain outlet? - TO CARRY WATER AWAY FROM THE UNDERDRAIN

4. What type of pipe should be used in an outlet? - WITHOUT PERFORATION & LAID WITH WATERTIGHT JOINTS

COMBINATION STORM SEWER AND UNDERDRAIN

A combination storm sewer and underdrain serves both as a part of the surface drainage system for a road and as a part of the subsurface drainage system. Serving as a storm sewer, it carries away surface water which enters it from inlets built for that purpose. Serving as an underdrain, it carries away underground water that flows into it directly, and it also collects water discharged into it from drains placed in the subgrade or the subbase.

A pipe is always used for a combination storm sewer and underdrain. The possible kinds of pipes are as follows:

1) Perforated corrugated metal pipe
2) Perforated asphalt coated corrugated metal pipe
3) Reinforced cement concrete pipe
4) Vitrified clay lined reinforced cement concrete pipe
5) Extra strength plain cement concrete pipe
6) Extra strength vitrified clay pipe

Cement concrete pipe or vitrified clay pipe must be of the bell-and-spigot style. All pipe must be laid in a trench, the width of which should not be more than 1 foot greater than the outside diameter of the pipe at a joint.

The bottom of the trench should be prepared as explained for a pipe culvert. Perforated metal pipe is laid with the holes up. Part of the upper section of each joint in concrete or clay pipe is left open, while the rest of the joint is sealed with mortar. The part of the trench below the middle of the height of the pipe should be backfilled with impervious soil taken from excavation for the project. This soil must be fully compacted under the

haunches of the pipe, and its surface should slope slightly upward from the pipe to the sides of the trench.

NOW ANSWER THESE QUESTIONS

1. What is the double purpose of a combination storm sewer and underdrain?

TO CARRY AWAY SURFACE WATER + SUB SURFACE WATER

2. What types of pipe are used for this combination? PERFORATED CORRUGATED METAL PIPE, PERFORATED ASPHALT COATED CORRUGATED M.P., REINF CEMENT CONCRETE PIPE, VITRIFIED CLAY LINED CEMENT CONCRETE PIPE, EXTRA STRENGTH CEMENT CONCRETE PIPE EXTRA STRENGTH VITRIFIED CLAY PIPE

3. How wide is the trench for this type of drainage structure? NOT MORE THEN 1' GREATER THEN O.D AT JOINT

4. How is the part of the trench below the middle of the height of the pipe backfilled? SHOULD BE FILLED WITH IMPERVIOUS SOIL + SLOPED UPWARD FROM PIPE TO SIDES OF TRENCH

5. What is meant by "impervious" material? SUCH AS FINE CLAY

THAT CAN SEAL OFF WATER

SUBGRADE DRAINS

Drains are placed in the subgrade to take care of water from a spring or seepage that cannot be cut off before it gets into the subgrade, or of water that may get into the subgrade from the surface of the road. If the water comes from the road surface, subgrade drains must always be located at low points, where the water would collect. It is almost impossible to repair a subgrade drain. If one gets plugged up, it cannot be cleared. As a result, the water that should be removed by the drain soaks into the subgrade. For this reason, each subgrade drain must be designed and built so that it will not stop working.

A subgrade drain should usually consist of a trench filled with granular material. The best material for such a drain depends on the kind of soil in which it is laid. Crushed stone may be used for drains in rock, gravelly soil, or material that does not soften when water stands on it. However, if crushed stone is used in soft clay or silty soil, the water that runs into the drain will carry with it fine soil particles which will soon plug the spaces between the particles of stone. In relatively fine soil, a drain made of clean concrete sand or clean sand-gravel will work satisfactorily for a long time. Actually, a certain volume of sand has almost as much space between its particles as does an equal volume of crushed stone. Since the spaces in sand are smaller, however, fine particles do not get in them to plug the sand drain. When subgrade drains are to be built through a soil that may plug the drains, the District Soils Engineer should help select the material to be used for the drains.

The material used for a subgrade drain must always be clean, and it must be handled so that no dirt gets into it while the drain is being built. Even a small amount of mud in the material will reduce greatly the speed with

which the drain will carry water away. After the drains have been built, they must be protected so that water carrying mud cannot run into them before the surrounding subgrade material is placed. If dirt gets into a drain during construction, the dirty material must be removed and replaced with clean material. A subgrade drain under a subbase should be covered with a layer of roofing paper or subgrade paper.

Unless a subgrade drain is under a superelevated roadway, or some other grade is shown on the drawings, the bottom of the trench for the part of the drain beneath the pavement should have a slope of 1/4 inch per foot toward the shoulder. The slope of the drain from the edge of the pavement to the outlet should be 1/2 inch per foot. The outlet should be located at such an elevation that water will not flow through the drain backward. When a drain is to discharge into a ditch, the outlet of the drain should not be too near the flow line of the ditch. If the outlet is too low, the drain may carry water back under the pavement when the ditch is running full of water.

Trenches for subgrade drains may be at right angles to the centerline of the roadway or may be skewed. Where the grade of the roadway is more than 1 percent, the trenches are usually skewed in order that the required depth of excavation will be reduced. The outlet ends of all subgrade drains must be marked with stakes and referenced on the Construction Drawings. During construction and just before final inspection, the Inspector should check the outlet ends of subgrade drains in embankments to make sure that they are open and the drains are working.

INSPECTOR'S CHECK LIST FOR PIPE CULVERTS

During construction of a pipe culvert, the Inspector should see to it that the following conditions exist.

1) The pipe came from an approved source and has been tested.
2) The pipe is unloaded, stored, and moved in such a way that it will not be damaged.
3) Pipe that does not meet the requirements of the Specifications in the field inspection is shipped back to the manufacturer or taken off the job.
4) The culvert is located so as to best meet field conditions, and the pipe is long enough.
5) The trench is excavated to the required depth in natural ground or in fully compacted embankment.
6) The bottom of the trench is at the right grade, and proper allowance has been made for camber.
7) The trench is excavated to the right width.
8) The material at the bottom of the trench will provide uniform and stable support for the pipe.
9) The bottom of the trench is shaped to fit the pipe, and holes have been dug for bells (when bell-and-spigot pipe is used).
10) The trench is braced safely.
11) The pipe is laid with tight joints, and mortar joints are cured properly.
12) The backfill material is free from large stones or lumps, and has the right moisture content for good compaction.
13) The backfill is placed slowly and evenly, and the material under the haunches of the pipe and between the pipe and the sides of the trench is fully compacted.

14) The pipe is protected against heavy construction loads.

NOW ANSWER THESE QUESTIONS

1. Where are subgrade drains located? AT THE LOW POINTS OF THE ROAD

2. How is a subgrade drain repaired if it fails? THEY CANT BE REPAIRED

3. Describe the material used in a subgrade drain. CRUSHED STONE CAN BE USED IN ROCK & GRAVELLY SOIL, OR MATERIAL THAT DONT SOFTEN WHEN WET — SAND

4. What happens when mud gets into the material placed in a subgrade REDUCES THE SPEED IN WHICH WATER IS TO BE CARRIED AWAY

5. Describe the problems if the outlet of a subgrade drain is placed either too high or too low. TOO HIGH WATER WILL FLOW BACKWARD — TOO LOW TO DISCHARGE DITCH WILL CAUSE WATER TO FLOW UNDER PAVEMENT WHEN DITCH IS RUNNING FULL

SECTION III

DRAINAGE REPORTING FORMS

The following page shows Page 17 of the plant book kept in each project office. It shows information to be recorded on delivery of pipe to the job site. You may be required to provide this information to the Project Engineer when pipe deliveries are made. Study the column headings so that you will be familiar with them.

Form 4221 Rev. 6-65
COMMONWEALTH OF PENNSYLVANIA
Department of Highways
Testing and Research

DATE REC'D	INVOICE	PRODUCER AND POINT OF MANUFACTURE	CLASS TYPE	DATE MADE	DIA.	LGTH. OF SECT.	NO. SECT.	TOTAL FEET	STA. TO STA. WHERE USED	ACCUM LIN FT.	DATE OF CERT.	LAB. REPT. REC'D.

Pipe Record County Route Sec. Plant Book Page 17

The following pages describe how your daily report of tests is to be completed. Study the directions for filling out the form, and compare them with the actual copy of the form which appears on page   . Be sure that you understand all of the entries.

COMPLETION OF FORM 4252

DAILY SUMMARY OF TESTS

Information:

1. Person who prepared sheet will sign name.

2. Project Engineer will sign Form 4252 to indicate that he has reviewed the test data.

3. Circle the proper heading for which tests were run.

4. The date is to be written at the top of the page.

5. The Engineering District Number is to be entered.

6. The County in which the project is located is to be filled in.

7. Fill in the route number.

8. Fill in the section of the route.

9. Enter the Prime Contractor's name or name of his firm. (Do not enter sub-contractors)

10. All Random Sample Tests will be written in Red on Form 4252. All other tests should be in ink.

11. Embankment and subgrade tests will appear on separate sheets.

12. If tests fail, show under "Remarks" the Report Number that corrects failing tests. (For instance, "See Report No. ____")

13. Show the proper compaction sheet number.

14. Since this is a Daily Report, it should be submitted to the District Office at the close of each working day.

15. Make a carbon copy for the job record.

16. Forms should be submitted to the attention of the Soils Engineer.

118.5
117.6
0.9

$$160\overline{).900}$$
1

.9).100
9
10
9
1

FORM 4252 REV 4-67
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HIGHWAYS
BUREAU OF MATERIALS TESTING AND RESEARCH

DAILY SUMMARY OF TESTS
MATERIALS GRADATION
AND
SOIL MOISTURE DENSITY RESULTS
(NUCLEAR OR SAND CONE)

Tested by: R. Witmer

Signature Project Engineer:

Item: Soils, Subgrade

DISTRICT 8-0 DATE 6/28/6

COUNTY York

ROUTE 441 SECTION 1

CONTRACTOR H. J. Williams Co., Inc.

FED. PROJ. NO. 100% State

Test No.	Location: Station	Location: Offset From	Design Height / Present Elev.	Compaction Control Data: Dry Density Field	Dry Density Max.	% Compaction	M. C. % Dry Wt. Field	M. C. % Dry Wt. Opt.	Percent Passing	Depth	Remarks
188	176+25	℄	Cut 639'	117.6	118.5	99.3	10.7	15.3			Subgrade Check Test for No. 183
189	179+00	10 RT.	Cut 632'	117.9	118.5	99.6	12.7	15.3			" Check Test for No. 186
190	196+00	℄	Cut 646'	142.2	128.6	110.6	5.2	10.3			Subgrade
191	195+50	6 RT.	Cut 646'	136.3	128.6	105.1	7.3	10.3			"
192	195+50	4'RT.	Cut 646'	133.4	128.6	103.9	6.5	10.3			"
193	197+00	3'LT.	Cut 644'	135.4	128.6	105.4	5.9	10.3			"
194	197+00	10'RT.	Cut 644'	130.0	128.6	101.1	6.9	10.3			"
195	198+10	℄	Cut 643'	131.2	128.6	102.3	8.1	10.3			"
196	198+50	7'LT.	Cut 642'	129.1	128.6	100.4	10.1	10.3			"
197	200+50	14'RT.	Cut 638'	132.9	128.6	103.4	6.1	10.3			"
198	200+75	℄	Cut 638'	136.7	128.6	106.4	7.6	10.3			"

.0369

82.5 | 3.050
2475
5750
4950
8000
7820

The following pages show how to complete the Report on Compaction Density. Study the directions and the form 478, and answer these questions:

1. How do you find the weight of sand in the test hole?

weight of SAND IN TEST Hole & upper cone subtract weight of SAND IN up cone & get weight of SAND IN Test Hole

2. How do you find the volume of the test hole?

WT of SAND IN Hole ÷ BY WT of Dry SAND Per CU FT.

3. How do you find the percent of moisture in your sample?

WT of Moisture ÷ By WT of Dry Sample X 100

4. How do you determine the weight of wet material from the test hole?

WT. of wet MATERIAL ÷ BY volume of Test Hole

5. How do you determine the degree of compaction?

WT. of Dry MATERIAL IN ONE CU FT.

÷ BY MAX Dry weight per CU. FOOT

$$\begin{array}{r} 17 \\ 5.57\overline{)1000} \\ 557 \\ \hline 4430 \\ 3899 \\ \hline 531 \end{array}$$

$$\begin{array}{r} 62.4 \\ 3.7 \\ \hline 4368 \\ 1872 \\ \hline 230.88 \end{array}$$

$$\begin{array}{r} 3.7 \\ 2.7\overline{)10.0} \\ 81 \\ \hline 190 \\ 189 \\ \hline 1 \end{array}$$

COMPLETION OF FORM 478

REPORT ON COMPACTION DENSITY

Embankment:

1. Complete an original for your own record and two carbon copies. One of these is for the Project Engineer. The other is for the District Office.

2. Circle the word "Embankment" after Type of Construction, and fill in the requested information on the top of the sheet.

3. Place the Federal Project Number in the upper right corner of the sheet, if the Project is a Federal Aid one.

4. The height above original ground should be the measured height of completed fill at the exact location where the test was taken. (Check elevation of fill with Locke level)

5. Record the laboratory number or Field Proctor number or Sample number from the Soils Report of the soil type to be used in Item 25.

6. Item 1 should be approximately 6 pounds to guarantee that the hole has been dug to sufficient depth.

7. In Item 4, enter fifteen (15) pounds. This is a constant value.

8. Draw a circle around the average specific gravity used in calculating Item 20.

9. Record the percentage retained on the 3/4 sieve on the bottom of the sheet. (N.B. Items 3 and 19 should be complete)

10. If 15% or more is retained on the 3/4 inch sieve, the material is too granular for testing and should be recorded as such in the blank space below Item 16.

11. When an embankment is composed of blasted rock, and no test can be run, a statement explaining fill conditions should be placed on the bottom of the sheet. For Example:

"A lift is composed of approximately 70% rock (Limestone) with rock fragments and A-6(2) soil as a binder. The material is placed in a 24 inch layer and rolled with a grid roller. (No movement under compacting equipment)"

12. If Item 26 is 100% or more, the zero air voids formula should be computed on the back of the sheet.

13. It is the responsibility of the Project Engineer to initial this form.

Subgrade:

The Form 478 is to be completed for subgrade the same as embankment with the following exceptions:

1. Circle the word "Subgrade" on the right top of the sheet.

.122
100
12200

.122
356.3) 43.70
35.63
8070
7126
9440
7126
2314

Form 47R Rev. 6-65
COMMONWEALTH OF PENNSYLVANIA
Department of Highways

REPORT ON COMPACTION DENSITY

Embankment and Subgrade

Fill out completely. Original to be retained with project records. Mail copy to District

Type of Construction 30" A.C.C.M. Pipe Embankment ______ Subgrade ______
Report No. 1 ______ Rt. 1033-4 Sec. ______ Co. Perry Date March 2, 1967
Test Sta. ______ + ______ at 72 Ft. Left of Centerline, at ______
______ Ft. above original ground. Time of Test 4:00 P.M.

NET WEIGHT OF MATERIAL FROM TEST HOLE

1. Wt. of wet material (+aggregate) from test hole + wt of container - - - = 5.57 lbs.
2. Wt. of container - - - = .87 lbs.
3. Wt. of material (+ aggregate) from test hole - - - = 4.70 lbs.

VOLUME DETERMINATION OF TEST HOLE

4. Wt. of sand + wt. of density-cone apparatus - - - = 15.00 lbs.
5. Wt. of sand left in density-cone + wt. of density-cone apparatus - - - = 8.99 lbs.
6. Wt. of sand in test hole and upper cone #4 - #5 - - - = 6.01 lbs.
7. Wt. of sand in upper cone - - - = 2.96 lbs.
8. Wt. of sand in test hole #6 - #7 - - - = 3.05 lbs.
9. Unit wt. of calibrated air dry sand - - - = 82.5 lbs./cu. ft.
10. Volume of test hole #8 ÷ #9 - - - = .0369 cu. ft.

MOISTURE CONTENT DETERMINATION *

11. Wt. of wet sample + pan - - - = 508 gm.
12. Wt. of dry sample + pan - - - = 464.3 gm.
13. Wt. of pan - - - = 108.3 gm.
14. Wt. of moisture #11 - #12 - - - = 43.7 gm.
15. Wt. of dry sample #12 - #13 - - - = 356.3 gm.
16. Percent moisture (#14 ÷ #15) 100 - - - = 12.3 gm.

DENSITY

PROCEDURE WHEN SAMPLE CONTAINS NO AGG. ON THE 3/4" SIEVE

17. Wt. per cu. ft. of wet material from test hole #3 ÷ #10 - - - = 127.4 lbs.
18. Wt. of dry material in one cu. ft. (100 x #17) ÷ (100 + #16) - - - = 113.5 lbs.

PROCEDURE WHEN SAMPLE CONTAINS AGG. ON THE 3/4" SIEVE

19. Wt. of aggregate retained on the 3/4" sieve - - - = 1 lbs.
20. Volume of aggregate retained on the 3/4" sieve #19 ÷ (SG** x 62.4) - - - = ______ cu. ft.
21. Wt. of wet material from test hole #3 - #19 - - - = 21 lbs.
22. Volume of wet material passing the 3/4" sieve #10 - #20 - - - = ______ cu. ft.
23. Wt. per cu. ft. of wet material from test hole #21 ÷ #22 - - - = ______ lbs.
24. Wt. of dry material in one cu. ft. (100 x #23) ÷ (100 + #16) - - - = ______ lbs.

COMPARISON OF DENSITIES

25. Max. dry wt. per cu. ft. (Test # ______ AASHO: T99, MC-U) - - - = 113.2 lbs.
25 a. Optimum moisture - - - = 14.8 %
26. Degree of compaction #18 ÷ #25 or #24 ÷ #25 - - - = 100.3 %
27. Minimum compaction requirement - - - = 95 %

** Average Specific Gravity Values; limestone = 2.7, gravel = 2.5, sandstone and sandy shale = 2.2 clay shale = 1.9 Volumetric Displacement Method for determination of Specific Gravity is acceptable.
* The moisture content may be determined by use of the SPEEDY MOISTURE TESTER

Test by J. Brady

The following page gives instruction on completing form 447, which is filled out and submitted to the laboratory with every sample. Study the instructions and the completed form to be sure you understand all of the entries.

PROCEDURES FOLLOWING WHEN COMPLETING

FORM 447 - SAMPLE IDENTIFICATION

1. Complete an original to accompany the sample, and two (2) carbon copies, one (1) for the job record, and one (1) for the District Office.

2. Omit purchase order number.

3. Name of producer or property owner will be - Right-of-Way - unless the material is manufactured or processed then the producers' name will be used.

4. Type of construction should describe the actual operation i.e.: Sub-base, Subgrade, Soil-Cement Shoulder, for use in embankment, etc.

5. Use the line labeled "Car Initials and No." for stating what tests are to be run on this sample.

Form 447 Rev. 5-61 COMMONWEALTH OF PENNSYLVANIA Department of Highways Testing and Research	SAMPLE IDENTIFICATION	Date: 6-30-67

Material, Brand, Trade Name, Etc. Crushed Limestone Purchase Order Number Contract

Name of Producer or Property Owner Pennsy Supply, Hummelstown, Pennsylvania

Type of Construction Sub-Base (1966 Specs) & Granular Pipe Backfill

For Use on Rt. 22021 Sec. 6 & 22008-3 Appl. | Place Collected Stockpile (Quarry)

Division No. 8-0 County Dauphin | Date Sampled 6-30-67

Contractor Kimbob, Inc. | Sampled by Lehman and Burrell

Quantity Represented Pre-Construction Sample | Title ME II CI II

Car Initials and No. Density and Moisture Requested

For Stone, Sand, Slag, Gravel, Etc., Sampled at Source of Supply

Location of Supply (P. O. or Rt. & Sta.) Twp., County

Source:—Quarry, Ledge, Boulder, Field Stone? Bank or Stream Bed?

Size of Screen Openings in Plant:

Railroad Connection of Plant: Daily Capacity

(Enclose in Tag, Wrap Tag Inside Parcel Post Packages)

Form 487 Rev. 3.67
COMMONWEALTH OF PENNSYLVANIA
Department of Highways
Bureau of Materials
Testing and Research

FIELD GRADING TESTS OF COARSE AGGREGATE

Date: 5-2-67

Type of Construction: Transit Mix	County: Lebanon		Purchase Order No. Contract
Contractor: Glasgow, Inc.	Rt. or Appl. 1005	Sec. 1	Dist. No. 8-0
Test by: C. Roth	Boro. or Twp. Lincoln Twp.		

Date Tested ______________

Car Initials & No. ______________

Tons Represented: ______________

Name of Producer:........

	WEIGHT LBS.	%	WEIGHT	%	WEIGHT	%	WEIGHT	%
Passing 4"			5-2-67					
Passing 3 1/2"			Trucks					
Passing 3"			Monthly sample					
Passing 2 1/2"			H. E. Millard, Palmyra					
Passing 2"								
Passing 1 1/2"	35.0	100	42	100				
Passing 1 1/4"								
Passing 1"	35.0	100	39.1					
Passing 3/4"								
Passing 1/2"	14.3	40.8	18.2					
Passing 3/8"								
Passing No. 4	0.4lb.	1.1	0.6					
Passing No. 8	0.2	0.6	0.4					
Passing No. 100								
Slag Wt. Per Cu. Ft. Compacted								

Above is an example of the Report on a Gradation test of coarse aggregate.

1. Copy the following figures in the third column of the form:

Passing No. 1 1/2" - 42 pounds

Passing No. 1" - 39.1 pounds

Passing No. 1/2" - 18.2 pounds

Passing No. 4 - 0.6 pounds

Passing No. 8 - 0.4 pounds

2. Now in the fourth column complete the percentages of material in this 42 pound sample.

Form 427 Rev 3-67
COMMONWEALTH OF PENNSYLVANIA
Department of Highways
Bureau of Materials
Testing and Research

FIELD GRADING TESTS OF FINE AGGREGATE

Date

Type of Construction	County	Purchase Order No.
Contractor	Rt. or Appl. Sec.	Dist. No.
Test by	Boro. or Twp.	

Date Tested

Car Initials & No.

Tons Represented:

Name of Producer:	GRAMS	%	GRAMS	%	GRAMS	%	GRAMS	%	GRAMS	%
Retained on 3/8"										
Passing 3/8"										
Passing No. 4										
Passing No. 8										
Passing No. 16										
Passing No. 30										
Passing No. 50										
Passing No. 100										
% Silt by Wash										
F.M.										

Above is an example of the report on a gradation test of fine aggregate:

1. Copy the following figures in the third column of the form:

Passing	3/8"	-	240.0 gram
Passing	No. 4	-	221.2 gram
Passing	No. 8	-	197.3 gram
Passing	No. 16	-	180.2 gram
Passing	No. 30	-	131.0 gram
Passing	No. 50	-	43.8 gram
Passing	No. 100	-	12.4 gram

2. Now in the fourth column complete the percentages of material in this 240 gram sample.

Various soils tests are made daily in earthwork construction by soils "technicians" who are assigned to a project. Nuclear density tests are an example. Special training is necessary for this type of work. "Moisture-Density" tests are another example. The following pages describe such a test, commonly called the "Proctor test". You should familiarize yourself with this material, as you may be called upon to aid in this work.

MOISTURE DENSITY TESTS

Moisture density tests are compaction tests to find out the density to which a soil can be compacted with various moisture contents and compactive efforts in the laboratory. The results of these tests are the terms "maximum density" and "optimum moisture". These tests can be interpreted to give considerable general information about the soil. The greatest density obtained in the test is called "maximum density" and the corresponding moisture is called "optimum moisture".

Definitions:

1. Optimum Moisture: The moisture content in the soil at which a given compactive effort will produce the maximum dry unit weight.

2. Maximum Density: The dry unit weight of a soil obtained by a given compactive effort at the optimum moisture content.

Proctor Test Procedure:

1. Gather sufficient sized sample - (12 to 16 pounds) and air dry to fairly low moisture content.

2. Sieve material through 3/4 inch sieve. Use only the material which passes the 3/4 inch sieve for the test.

3. Thoroughly mix the material for the most even distribution of moisture and various types of soil.

4. Weigh the mold without its collar and record the weight on Form 4247.

5. Assemble mold.

6. Fill mold 1/2 to 2/3 with loose material. This height will vary with different types of soil.

7. Place the mold on a solid base. AASHO recommends 200 pound block of concrete.

8. Tamp - using 25 evenly spaced and free-falling blows.

9. Scarify the tamped surface and place a second loose layer in the mold.

10. Tamp with 25 more blows.

11. Scarify the surface and place the third loose layer in the mold.

12. Tamp - 25 more blows.

N.B. The three tamped layers should have reached a height which is above the break of the collar and the barrel but not necessarily to the top of the collar. Wetted material, not being used in the mold, should be covered with a wet burlap bag to prevent escape moisture.

13. Loosen the top wing nuts and gently remove the collar, with a slight twisting motion, being careful not to undercut the material. Any undercuts must be refilled with material, pressed back into place and struck off evenly across the top of the mold barrel.

14. Brush off excess material from the sides and bottom of the mold.

15. Weigh material and mold, without collar, and record on Form 4247 (Column A). N.B. All formulas for computations are listed on Form 4247.

16. Loosen barrel wing nuts and remove soil from the barrel.

17. Take a speedy moisture or hot plate test from a sample taken from the center of the soil core. Record on Form 4247 (Column I).

18. Remix and break up all lumps to original size.

19. Mix thoroughly to prevent concentration of moisture which will appear in lumps.

20. Clean and reassemble mold.

orm 4247 Rev 4-57
OMMONWEALTH OF PENNSYLVANIA
Department of Highways
Bureau of Materials
Testing & Research

Field Test No ____________

METHOD FOR CALCULATION OF MOISTURE-DENSITY RELATIONSHIP

District ____________
Route No. ____________
County ____________
Station ________ Rt. ____ Lt. ____
Contractor ____________
Date ____________

	A	B	C	D	E	F	G	H	I	J
Trial No.	Wet Wt. Sample + Wt. Mold Lbs.	Wet Wt. of Sample lbs.	Wet Weight per Cu. Ft.	Wet Soil + Pan gm.	Dry Soil + Pan gm.	Moisture Loss gm.	Weight of Pan	Dry Wt. Soil	% Moisture	Dry Weight per Cu. Ft.
1										
2										
3										
4										
5										
6										

Procedure:

Wt. of Mold ________ lbs.

B = A - Mold

C = B x 30

F = D - E

H = E - G

$$I = \frac{F}{H}(100)$$

$$J = \frac{C \times 100}{100 + I}$$

Optimum Moisture ______ %

Maximum Density ______ P.C.F.

MC - C ☐

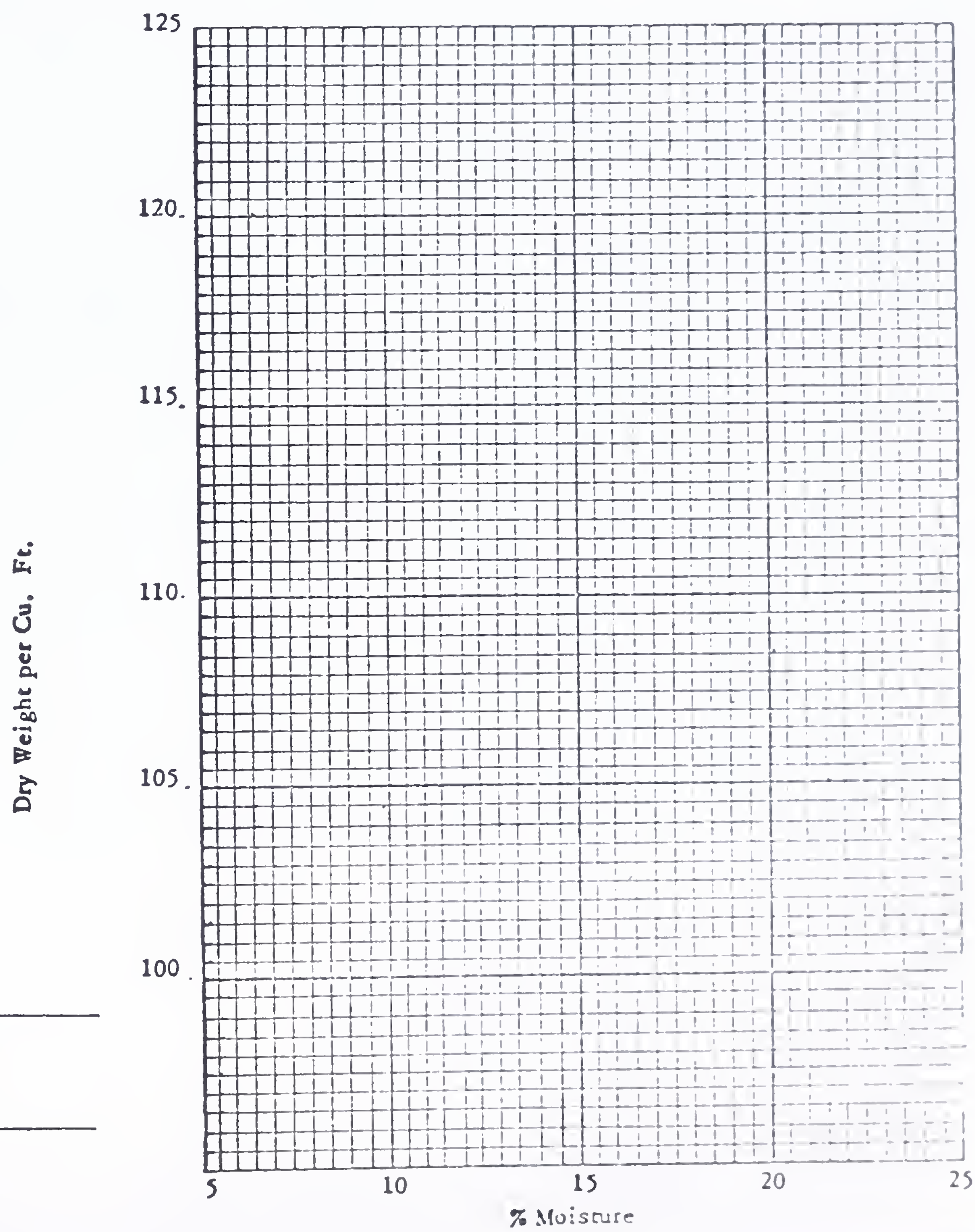
MC - U ☐

Test By

____

Check By

____



FIELD INSPECTOR'S DIARY

The most important document you will be responsible for in Drainage Inspection is the Inspector's Diary. This is a permanent part of any construction project. Its contents can become legal evidence in court, should the necessity ever arise. Therefore, you should complete your diary with great care every day the project is in operation.

On the next page is a sample page from a diary. Study it, and then fill it out, using the following information:

You are working on Project 1005, Section 2. Your book (Bk) number is 0122, and the day is today. The weather today is clear, and at 8:00 a.m. the temperature was 54°, which rose to 74° by 3:00 p.m. The Acme Construction Company is the contractor. You are placing pipe backfill from Station 645+25 to 647+82. The Contractor has a front end loader, four mechanical tampers and two hand tampers at work. One of his foremen is also at the location. In the afternoon, some large rocks got mixed in with the granular fill being used in the embankment. You found it necessary to notify the foreman to have these removed, and to request him to examine the source of the material, so that no more rocks would disturb the progress of the work. Your report covers only page 13 of book (Bk) No. 0122. There is a sketch of the pipe in this area, which appears in the Sketch-Computation book (S/C Bk) on page 84.

PROJECT ______________________________ BK # ___ ___ ___ ___ ___

______________________________ Page 13

TEMP A.M.____ P.M.____ DATE / /

WEATHER ______________________________ OFFICE # ____

CONTRACTOR ______________________________

____

NO. OF MEN ______________________________

____

EQUIPMENT ______________________________

____

____

TYPE OF OPERATION STA TO STA

THIS REPORT COVERS:

BK # ___ ___ ___ ___ ___ PGS.

____
INSPECTOR

BK # S/C ___ ___ ___ ___ ___ PGS.